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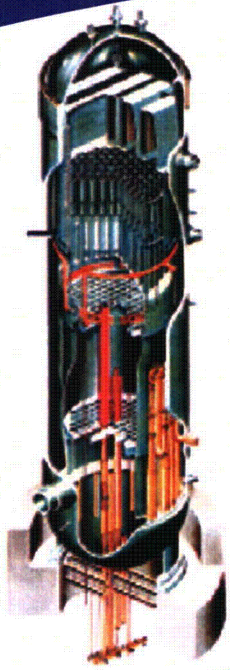
BWRVIP-41NP, Revision 4: BWR Vessel and Internals Project

BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines



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BWRVIP-41NP, Revision 4: BWR Vessel and Internals Project

BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines

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Final Report, September 2014

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BWRVIP-41, Revision 3: BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines. EPRI, Palo Alto, CA: 2009. 1021000.

This publication is a corporate document that should be cited in the literature in the following manner:

BWRVIP-41NP, Revision 4: BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines. EPRI, Palo Alto, CA: 2014. 3002003093NP.

REPORT SUMMARY

The Boiling Water Reactor Vessel and Internals Project (BWRVIP), formed in June 1994, is an association of utilities focused exclusively on BWR vessel and internals issues. This BWRVIP report provides information on potential failure locations in BWR/3–6 jet pump components and recommends an inspection program designed to ensure that the integrity of all jet pump safety functions is maintained. This Revision of BWRVIP-41 (Revision 4) is based on the previously published Revision 3 and incorporates the results of BWRVIP inspection optimization as documented in *BWRVIP-266: BWR Vessel and Internals Project, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.*

Background
Based on industry jet pump inspection experience and a safety assessment completed by the BWRVIP, entitled *Safety Assessment of BWR Reactor Internals* (BWRVIP-06-Revision 1-A, EPRI 1019058), it has been determined that inspection and evaluation (I&E) procedures play a role in ensuring the long-term integrity of the jet pump safety functions and maintaining the design basis of the jet pump assembly. This report, *BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines*, was developed and is maintained to present appropriate inspection recommendations to assure safety-function integrity.

Objective
To provide generic inspection guidelines that will ensure the continued integrity of all jet pump safety functions and maintain the design basis of the jet pump assembly.

Approach
A group of utility and industry experts evaluated available information—including BWR inspection data and information on intergranular stress-corrosion cracking (IGSCC), fatigue, and embrittlement—to identify potential failure locations in BWR/3–6 jet pump components. The consequences and likelihood of a failure at each location were evaluated. Factors considered included component function, plant-specific configuration variations, cracking susceptibility, and inspection history. The project team then made both baseline inspection and reinspection recommendations based on BWR type and (where appropriate) plant-specific configuration differences. With baseline inspections now complete, this revision of the guideline presents only recommendations for periodic reinspection. New data, for example, changes to susceptibility trends identified as inspection data accumulates, are incorporated into this guidance over time. As such, periodic revision of this guideline over time is anticipated to occur.

Results

These inspection guidelines encompass all welded and bolted locations identified from design drawings of the jet pump assembly. They present cracking-susceptibility considerations for the jet pump, as well as the consequences of failure at each location. The susceptibility and consequence considerations, coupled with plant operating experience, are used to establish and maintain a comprehensive inspection program. The guidelines also discuss cases in which the scope of the inspection may need to be expanded and describe areas of the assembly that are not inspectable. Finally, the guidelines address loading considerations and provide flaw evaluation procedures to determine allowable flaw sizes for those locations where flaw sizing is relevant.

EPRI Perspective

The BWRVIP undertook an extensive program to develop and maintain a comprehensive set of guidelines that will provide every member utility with the necessary information to make cost-effective decisions on degradation management for key plant components. This series of I&E guidelines provides BWR owners with NRC-approved tools to answer questions on what needs to be inspected, when it needs to be inspected, and the technical basis for run-repair decisions when degradation is observed. Utility implementation of these guidelines for safety-critical BWR internals will ensure that components have not approached safety limits, thus confirming their serviceability.

Keywords

Boiling Water Reactor
Flaw evaluation
Jet pump assembly
Inspection strategy
Stress-corrosion cracking
Vessels and internals

RECORD OF REVISIONS

Revision Number	Revisions
BWRVIP-41	Original Report (TR-108728)
BWRVIP-41, Rev. 1	TR-108728 was revised to incorporate changes proposed by the BWRVIP in responses to NRC Requests for Additional Information, recommendations in the NRC Safety Evaluation (SE), and other necessary revisions identified since the last issuance of the report. In addition, the report includes revised guidance for inspecting jet pump wedges and incorporates the new jet pump beam inspection recommendations recently published in BWRVIP-138. All changes except corrections to typographical errors are marked with margin bars. The NRC SE for the original BWRVIP-41 report and the NRC Final Safety Evaluation accepting the original report for referencing in license renewal applications are included as appendices. Non-essential format changes were made to comply with the current EPRI publication guidelines. Appendix B added: NRC Final Safety Evaluation. Appendix C added: NRC Acceptance for Referencing Report for Demonstration of Compliance with License Renewal Rule. Details of the revisions can be found in Appendix D.
BWRVIP-41, Rev. 2	BWRVIP-41, Revision 1 was revised to incorporate changes proposed by the BWRVIP to include the results of comprehensive fracture mechanics evaluations performed on Group 2 and Group 3 jet pump beam designs documented in BWRVIP-138 Revision 1 (EPRI 1016574) and other necessary revisions identified since the last issuance of this report. All changes since the last issuance of this report except corrections to typographical errors are marked with margin bars. Details of the revisions can be found in Appendix E.
BWRVIP-41, Rev. 3	BWRVIP-41, Revision 2 was revised to incorporate an inspection strategy and leakage evaluation for inaccessible welds. All changes, except corrections to typographical errors, are marked with margin bars. Details of the revision can be found in Appendix F.
BWRVIP-41, Rev. 4	BWRVIP-41, Revision 3 was revised to incorporate changes to the periodic inspection program based on a detailed evaluation of plant operating experience. This evaluation is documented in BWRVIP-266, *BWR Vessel and Internals Project: Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.* This revision addresses only ongoing periodic inspection recommendations as all baseline inspections have been completed. Details of the revision can be found in Appendix G.

EXECUTIVE SUMMARY

Based on industry jet pump inspection experience and a safety assessment completed by the BWR Vessel and Internals Project (BWRVIP), "Safety Assessment of BWR Reactor Internals (BWRVIP-06-Revision 1-A)", EPRI Report1019058, December 2009, it has been determined that inspection and evaluation procedures have a role in assuring the long term integrity of the jet pump safety functions and maintaining the design basis of the jet pump assembly. The safety functions include ensuring 2/3 core height re-flooding capability, and maintaining Low Pressure Coolant Injection (LPCI) operability for those plants that use the recirculation system to inject LPCI.

This Inspection and Evaluation (I&E) Guideline provides information on potential failure locations in BWR/3-6 jet pump components. For each location, a discussion of the function, configuration, susceptibility, loading, and consequences of failure is provided. A summary of field experience is also provided. It was determined that many of the jet pump locations are susceptible to cracking due to Intergranular Stress Corrosion Cracking (IGSCC), fatigue or both. Embrittlement was also considered, but was found not to be a significant degradation mechanism for the jet pump components. Also, in evaluating the consequences of potential cracking, the conclusion for some locations is that significant cracking can be tolerated without loss of essential jet pump safety functions.

This Guideline is intended to present the appropriate inspection recommendations to assure safety function integrity. Economic and normal operational consequences of cracking are not directly factored into the recommendations. The inspection recommendations are dependent on BWR type and, where appropriate, plant-specific configuration differences. It is the intent that, for BWRVIP members, these guidelines can be followed in the place of prior GE SILs (Services Information Letters) related to safety to assure the essential safety functions of the jet pump.

Finally these guidelines include documentation that provides information necessary to comply with the technical information requirements of the appropriate section of the license renewal rule, 10CFR54.

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1 INTRODUCTION

1.1 Background

Prior to issuance of the original version of BWRVIP-41, jet pump failures had been addressed by a number of General Electric Service Information Letters (GE SILs). In February of 1980, a jet pump hold-down beam failure was reported at one site. Subsequent inspections revealed similar cracks in other units. In June 1980, GE issued SIL No. 330, "Jet Pump Beam Cracks" [1] to highlight the problem of jet pump beam cracking. SIL No. 420, "Inspection of Jet Pump Sensing Lines," [2] was issued in March of 1985 and recommended VT-3 inspections of the sensing lines. SIL No. 551, "Jet Pump Riser Brace Cracking," [3] was issued in February of 1993 and provided recommendations for inspections of riser braces. In October of 1993, GE provided additional jet pump inspection recommendations through the issuance of SIL No. 574, "Jet Pump Adjusting Screw Tack Weld Failures." [4]

The BWR internals safety assessment conducted in 1995 and documented in BWRVIP-06, Revision 1-A [5] concluded that inspection and evaluation procedures play a role in assuring the long-term integrity of the jet pump safety functions and maintaining the design basis of the jet pump assembly. As a result, the BWRVIP developed a jet pump inspection and evaluation guideline (BWRVIP-41: *BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines*) that was published in October of 1997 as EPRI Report TR-108728 and was subsequently implemented by member utilities. The final Safety Evaluation (SE) of BWRVIP-41 was issued in February of 2001. Subsequently, in 2001 NRC accepted BWRVIP-41 for referencing in license renewal applications based on the content of Appendix A to BWRVIP-41, "*Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21).*"

In September of 2005, the BWRVIP published Revision 1 of BWRVIP-41 as EPRI Report 1012137. This revision incorporated changes made in response to NRC Requests for Additional Information and Safety Evaluations received as part of the NRC review of the original report. This revision also included new guidance on jet pump beam inspections and restrainer bracket and wedge inspections and changed the visual examination technique specified from MVT-1 to EVT-1.

GEH SIL 660, "BWR-5 Riser Piping Cracking," [6] was issued in response to identification of a large FIV-induced fatigue crack in the fall of 2008. Subsequently, BWRVIP letter 2009-202 [7] was issued on June 18, 2009 to provide interim guidance and called for inspection of all riser pipe to riser brace welds and jet pump wedges on an accelerated schedule.

In July of 2009, BWRVIP published Revision 2 of BWRVIP-41 as EPRI Report 1019570. Revision 2 incorporated the results of comprehensive fracture-mechanics evaluations performed on Group 2 and Group 3 jet pump beam designs, previously documented in BWRVIP-138, Revision 1 [8]. Other minor revisions to the report were also made.

BWRVIP-41 Revision 3 was published by the BWRVIP in September 2010 as EPRI Report 1021000. This revision added inspection and flaw evaluation guidelines for inaccessible jet pump assembly welds. The approach utilizes inspection results from similar accessible welds to assess the condition of the inaccessible welds.

Since implementation in 1997, all accessible jet pump assembly welds in the U.S. fleet have been inspected at least once. Baseline examination of high priority locations was completed over a 6-year interval and baseline examination of medium and low priority locations was completed over 12 years. As of 2011, more than half of the high priority inspection locations and a significant portion of the medium and low priority locations have now been re-inspected.

In 2009, the BWRVIP began a comprehensive inspection optimization program to collect and evaluate field inspection data. The results of the evaluation are used to better assess the susceptibility of various component locations to degradation and to support revisions to inspection program criteria. This Revision 4 to BWRVIP-41 represents a substantial revision to the jet pump assembly inspection criteria based on the results of the inspection optimization program evaluation. BWRVIP-266 [9] provides the technical bases for the changes.

1.2 Objectives and Scope

This Jet Pump Inspection and Flaw Evaluation (I&E) Guideline contains generic guidelines intended to present inspection recommendations sufficient to assure continued integrity of all jet pump safety functions and to maintain the design basis of the jet pump assembly. Economic and normal operational consequences of cracking are not factored into the recommendations. The specific safety functions of the jet pump assembly are to maintain the ability to reflood the reactor to 2/3 core height in an accident scenario and, for some plants, to provide a path for Low Pressure Coolant Injection (LPCI) into the core. It is the intent that, for BWRVIP members, this Guideline can be followed in the place of prior GE SILs (Services Information Letters) related to safety (see Section 3.2) to assure the essential safety functions of the jet pumps. The Licensee is encouraged, however, to review all SILs to determine any non-safety commercial issues that need to be addressed, e.g., operating procedures and performance monitoring.

The Guideline addresses the following issues:

- Evaluation of any potential cracking locations on the jet pump assembly
- Categories of plants for which inspection needs differ
- Extent of inspection for each location
- Flaw evaluation procedures to determine allowable flaw sizes for locations where flaw sizing is relevant

This I&E Guideline provides design information on the jet pump geometries and weld locations for BWR/3-6 plants (BWR/2 plants do not contain jet pumps). Table 1-1 shows the plant configurations that were specifically evaluated in preparing this Guideline. Configuration and material information included in the guideline is based on the best information available. Plants are advised to confirm the accuracy of these configurations to evaluate the applicability of the inspection recommendations. In addition, plants not listed in Table 1-1 should obtain their configuration and material information.

Table 1-1
Plants Configurations Evaluated

Plant Type	Plant Names
BWR/3	Pilgrim, Monticello, Quad Cities 1,2, Dresden 2,3, Santa Maria de Garoña
BWR/4	Vermont Yankee, Fermi 2, Hope Creek 1, Limerick 1,2, Susquehanna 1,2, Browns Ferry 1,2,3, Peach Bottom 2,3, Brunswick 1,2, Hatch 1,2, Cooper, Fitzpatrick, Duane Arnold
BWR/5	LaSalle 1,2, Laguna Verde, Nine Mile Point 2, WNP2
BWR/6	Perry 1, Grand Gulf 1, River Bend, Clinton 1, Cofrentes

The Guideline's scope addresses all welded and bolted locations identified from design drawings of the jet pump assembly. A typical jet pump assembly configuration is shown schematically in Figure 1-1. This figure and other more detailed figures, identify the welded and bolted locations.

Susceptibility considerations for the jet pump are presented, as well as the consequences due to failure at each location. The susceptibility and consequence considerations are factored into the inspection recommendations.

The Guideline presents inspection approaches which vary depending on the type of plant and its associated jet pump configuration. Inspection options are also presented which consider implementation of repairs.

Load combination recommendations which can be followed in performing plant-specific analyses are provided. Flaw evaluation methodologies are provided for those locations where flaw evaluation is appropriate.

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Figure 1-1
Typical Jet Pump Assembly

1.3 Implementation Requirements

Note that, as of the publication date of this report, the revisions designated herein have not been approved by the NRC. The revised inspection recommendations in this report shall not be implemented immediately upon issuance of the report. Rather, the BWRVIP will notify users at a later time when implementation can be initiated.

Once utilities are notified by the BWRVIP that the report should be implemented, the inspection and evaluation guidance in Sections 3, 4 and 5 of this report will be considered "needed" in accordance with the requirements of Nuclear Energy Institute (NEI) 03-08, Revision 2, *Guideline for Management of Material Issues* [10]. The remaining sections are for information only.

2 JET PUMP ASSEMBLY ANALYSIS

2.1 Jet Pump Assembly Configuration and Function

The jet pumps are located in the annulus region between the core shroud and the vessel wall and provide core flow to control reactor power. Between 6 and 12 pairs of jet pumps are found in BWR/3 through BWR/6 plants, depending on plant rating. BWR/2 plants do not contain jet pumps. During normal operation, each pair of jet pumps is driven by flow from a common riser pipe. The jet pump drive flow is pumped through the recirculation system through the riser and into each jet pump. Additional fluid from the annulus region is entrained into the jet pump flow which is then directed to the lower plenum region.

Figure 1-1 shows a typical jet pump assembly. Each jet pump assembly is composed of two jet pumps and a common riser assembly. The riser assembly is a pipe, internal to the RPV, which connects the recirculation pump discharge line to the jet pump pair. A riser brace attaches the riser pipe to the vessel wall to provide lateral support.

Each jet pump has an inlet-mixer assembly and a diffuser assembly. The inlet-mixer assembly consists of a 180-degree elbow, a nozzle section with suction inlets, and a mixing section. The inlet-mixer assembly is clamped to the riser transition piece by the beam-bolt assembly, and fits into a slip joint at the top of the diffuser assembly. A restrainer bracket attached to the riser provides lateral support for each mixer section to increase the stiffness of the assembly and reduce the effects of vibration. The diffuser assembly consists of a gradual conical section terminating in a straight cylindrical section at the lower end which is welded to the shroud support plate. Instrumentation monitors jet pump flow through the diffuser to ascertain individual and collective jet pump flow rates under operating conditions.

For post-accident core re-flooding, the jet pump assembly assures re-flooding to no less than 2/3 core height. Assuming intact jet pump assembly, there is no recirculation line break scenario which can prevent re-flooding of the core to 2/3 core height, the height of the jet pump suction inlets.

An additional safety function of the jet pump assembly at some plants is to provide a flow path for LPCI flow into the core. All BWR/3s and BWR/4s except Hope Creek 1, and Limerick 1 and 2 inject LPCI through the jet pumps.

2.2 Susceptibility Factors

Within the jet pump assembly there are a number of factors that affect susceptibility. Materials, water environment, loading (both static and dynamic), and stresses attributed to either manufacture or to plant operation, all contribute to the jet pump's susceptibility. Many different materials and material conditions are present in the jet pump assembly, making this component difficult to analyze without looking at each sub-component separately and in detail.

There are three key degradation mechanisms that must be considered when analyzing the jet pump assembly sub-components: Intergranular Stress Corrosion Cracking (IGSCC), fatigue, and thermal embrittlement. Each will be discussed separately in the following sections, and the applicability of each of these degradation factors to each jet pump sub-component is summarized in Section 2.3. In addition, Irradiation Assisted Stress Corrosion Cracking (IASCC) was considered, but it was determined that the fluence levels are not high enough in the jet pump assembly locations to make IASCC a potential degradation mechanism.

2.2.1 Intergranular Stress Corrosion Cracking (IGSCC)

The occurrence of IGSCC relies on the combined presence of an aggressive environment, a susceptible material, and tensile stress.

2.2.1.1 Environment

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2.2.1.2 Materials

From the material perspective, there are a large number of parameters that determine the component's resistance to IGSCC. These parameters include:

- material (304, 316, 304L, 316L, Alloy 600, Alloy 182, X-750, and Stellite)
- material product form (wrought plate, forging, and casting)
- material condition (annealed and welded)
- material chemistry (composition, e.g. carbon level)
- component form (seamless pipe, rolled and welded pipe)
- type of weld/weld design (fillet and groove)

- welding process (shop and field)
- weld filler material product form (flux shielded vs. wire)

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2.2.1.3 Tensile Stress

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2.2.1.4 Operating Experience: IGSCC

Stainless Steel Weld HAZs:
To date, jet pump assembly weld and weld HAZ-related IGSCC performance is very good [9]. Where observed, degradation is found to be limited to a particular subset of weld locations and jet pump assembly design configurations

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2.2.2 Fatigue

Fatigue is the term given to both crack initiation and subcritical crack growth under the influence of fluctuating or cyclic applied stresses. There are three sources of fatigue significant to the BWR: 1) system cycling fatigue (low-cycle fatigue), 2) high-cycle thermal fatigue, and 3) vibration-induced fatigue. System cycling refers to changes in the reactor system which cause variations in pressure and temperature at the component. Examples of system cycling are start-up, shutdown, SCRAM, and safety relief valve (SRV) blowdown. System cycling is generally accounted for in the initial design analysis. High-cycle thermal fatigue (e.g., thermal mixing) is generally not an issue for jet pump components. This leaves high-cycle fatigue due to vibration as the primary fatigue issue for the jet pump components.

2.2.2.1 Fatigue Load Sources

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2.2.2.2 IGSCC Interaction

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2.2.2.3 Operating Experience: Fatigue

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2.2.3 Embrittlement

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2.3 Potential Failure Locations

The potential failure locations discussed in this section are based closely on the list of potential failure locations for the jet pump assembly presented in BWRVIP-06, Revision 1-A [5]. However, some of the locations were combined or separated into different parts to facilitate the susceptibility analysis. Therefore, the list of locations presented here does not exactly correspond to those identified in BWRVIP-06, Revision 1-A.

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For each jet pump location a discussion of its function, configurations, loading (pertaining to crack initiation and/or crack growth during normal operation), susceptibility, failure consequences, and inspection recommendation technical basis are given in the following sub-sections. The figures included in this section are intended to show the general design features of each of the locations, and therefore some features shown may not be applicable to all plants. The licensees should verify their plant-specific configurations for applicability with respect to the component description, figures, and materials shown in this guideline. Loading information provided in Section 2.3 is meant to give a generic description of the types of loads applied to each location. A more thorough discussion of applicable loads is found in Section 4.

2.3.1 Riser Brace

2.3.1.1 Function

The riser brace attaches the riser pipe to pads which are welded to the vessel wall. Its main function is to limit the vibration and maintain the orientation of the jet pump assembly. The riser brace leaves are designed to be flexible enough to accommodate the differential thermal expansion between the stainless steel riser pipe and carbon steel pressure vessel.

2.3.1.2 Configurations – Locations RB-1 to RB-5

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Figure 2-1
Typical Primary Single-Leaf Riser Brace

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Figure 2-2
Typical Primary Double-Leaf Riser Brace

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Figure 2-3
Typical Secondary Double-Leaf Riser Brace

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Table 2-1
Riser Brace Configurations

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2.3.1.3 Loading

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2.3.1.4 Susceptibility

Jet pump riser braces can suffer from two forms of environmentally assisted cracking, IGSCC of stainless steel heat affected zones (HAZs) and fatigue.

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2.3.1.5 Failure Consequences

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2.3.1.6 Inspection Recommendations

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2.3.2 Jet Pump Holddown Beam and Bolt

Jet pump beam failures have been extensively studied and documented in a recent BWRVIP report, BWRVIP-138, Revision 1 [8]. The discussion and inspection recommendations below are extracted from that report. The reader is referred to BWRVIP-138, Revision 1 for additional information.

2.3.2.1 Function

The jet pump holddown beam and bolt assembly secures the inlet mixer assembly to the riser transition piece. During normal operation the beam is locked into place, and the beam bolt is torqued to a specified preload value.

2.3.2.2 Jet Pump Beam Design and Configurations

The inlet-mixer section of each jet pump, which extends from the entrance of the 180° bend (elbow) to the slip joint with the diffuser, is shown in Figure 1-1. The inlet-mixer is held in place by a nickel-base Alloy X-750 beam stainless steel bolt assembly located in the riser transition piece. The beam ends are positioned in pockets in the transition piece, and the beam installation pre-load is transferred to the inlet-mixer elbow through a bolt located in the center of the beam. As described in the following paragraphs, four different beam designs exist. The BWR/3 design is included for historical interest. Since the BWR/4-6 design is interchangeable with the BWR/3 design, all BWR/3 replacement beams are of the newer designs.

2.3.2.2.1 BWR/3 Beam Design

The BWR/3 beam design was fabricated from a closed-die forging of Alloy X-750 material. The beams were subsequently equalized at 1625°F (885°C) for 24 hours, followed by aging at 1300°F (704°C) for approximately 20 hours. This heat treatment condition was referred to as 'equalized and aged' (EQA). Since the process used a closed die forging to achieve near net shape, only portions of the beam (the bolt hole region and the transition region) were machined. Most of the beam surface, including the tapered region, was left in the as-forged condition, although subsequent grinding of the surface was required by the fabrication drawing. Prior to final assembly, the beam was liquid penetrant examined. At the time of the publication of BWRVIP-41, Revision 1, no BWR/3 beams remained in service. Figure 2-4 shows the BWR/3 beam assembly.

2.3.2.2.2 BWR/4-6 Beam Design – Group 1

The Group 1 BWR/4-6 design beams used the same material and heat treatment as the BWR/3 design, and were also fabricated from closed die forgings. Similar to the BWR/3 design, the surfaces of the beam were both as-forged and machined. The final beam surfaces were also examined by liquid penetrant prior to final assembly. The major change in the beam design was dimensional – the beam depth increased from 2.02 to 2.30 inches (51.3 to 58.42 mm). In addition, the installation preload was increased from 25 to 30 kips (111 kN to 133 kN). At the time of the publication of BWRVIP-41 Revision 3, no BWR/4-6 Group 1 beams remained in service. Figure 2-5 shows the Group 1 BWR/4-6 beam assembly.

2.3.2.2.3 BWR/4-6 Beam design – Group 2

As a result of the failures of the equalized and aged beams (BWR/3 and Group 1 designs), the heat treatment of the beam material was changed. The revised heat treatment consisted of solution annealing at 2000°F (1093°C) for 1-2 hours, followed by water quench and then by aging at 1300°F (704°C) for approximately 20 hours. This heat treatment is referred to as 'high temperature anneal and aged' (HTA). The change to the HTA heat treatment was combined with a reduced preload, from 30 kips to 25 kips (133 to 111 kN). The initial beams were manufactured from closed die forgings, with the attendant combination of machined and as-forged surfaces, followed by liquid penetrant examination of the final beam surfaces. Beginning in 1994, some of the Group 2 beams were supplied as open-die forgings and as a result were machined on all surfaces, removing any as-forged surfaces. Liquid penetrant examination of final machined surfaces was also performed. Another change that occurred in 1994 was the addition of a baseline inspection by ultrasonic techniques (UT) of the BB-1 and BB-2 regions prior to installation. Since the Group 1 and Group 2 beams are dimensionally identical, Figure 2-5 also represents the configuration of the Group 2 beam assembly.

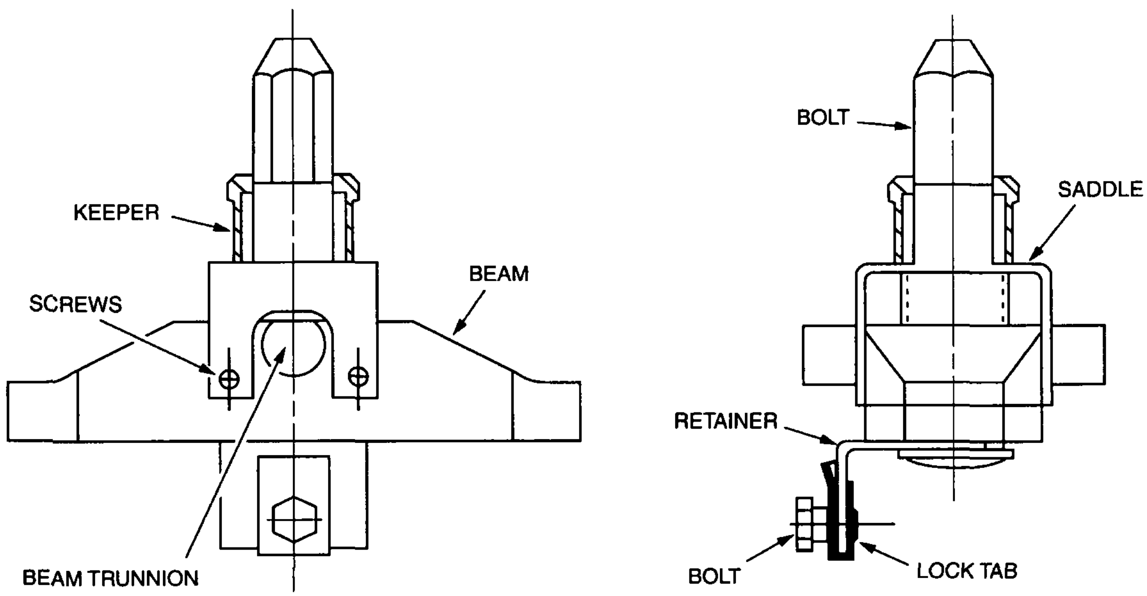

Figure 2-4
BWR/3 Beam-Bolt Assembly

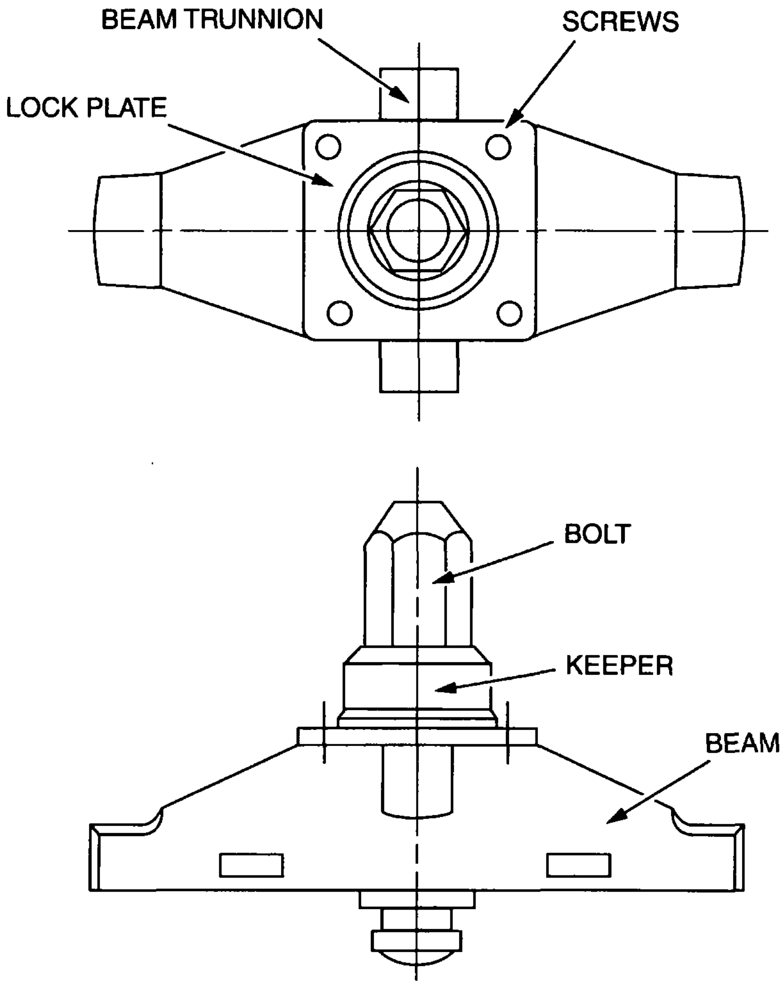

Figure 2-5
BWR/4-6 Beam Bolt Assemblies (Groups 1 and 2)

2.3.2.2.4 BWR/4-6 Beam Design – Group 3

Group 3 beams were introduced in 2001. The beam is fabricated from an "open die" bar forging. The beam is machined on all surfaces and subsequently liquid penetrant examined. The rectangular bar forging is fabricated from Alloy X-750 with the "HTA" heat treatment. The material is tested in accordance with MIL-DTL-24114F (the 'rising load test'). This beam-bolt assembly also incorporates a "ratchet" lock plate and keeper in place of the tack welded keeper used in the previous beam-bolt assembly designs. The beam has been made thicker in the center and the ends to reduce the mean stress in the beam after installation. Figure 2-6 shows the configuration of the Group 3 beam assembly.

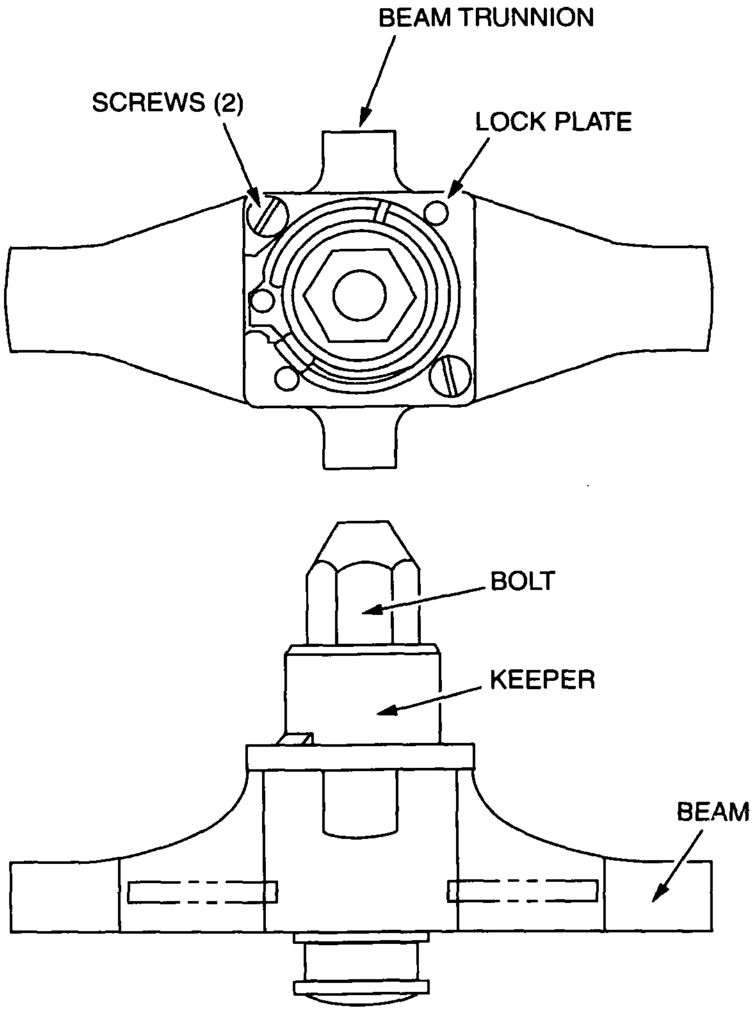

Figure 2-6
BWR/4-6 Beam Bolt Assembly (Group 3)

2.3.2.3 Inspection Regions

As discussed in Section 2.2.1.4, jet pump beam cracking has occurred in three different locations, warranting non-destructive examination (NDE) of all three regions where cracking has occurred. All three regions are shown schematically in Figure 2-7.

Since the loading results in a bending stress that is tensile on the top surface of the beam and compressive on the bottom surface, IGSCC originating on the bottom surface of Alloy X-750 beam is highly unlikely. In addition, any IGSCC that may form would preferentially orient in the transverse (made at right angles to the long axis of the beam) direction due to the bending stress. It is therefore important that the inspection technique be directed towards cracking with significant transverse orientation. Any transverse oriented beam cracking detected during an examination should result in the beam's replacement prior to restarting the plant unless the flaw can be demonstrated by an EVT-1 inspection to be wholly located in the "exclusion zone" as shown in Figure 2-7. For this case only, the beam is acceptable for continued service for one additional operating cycle and must be re-inspected at the next refueling outage.

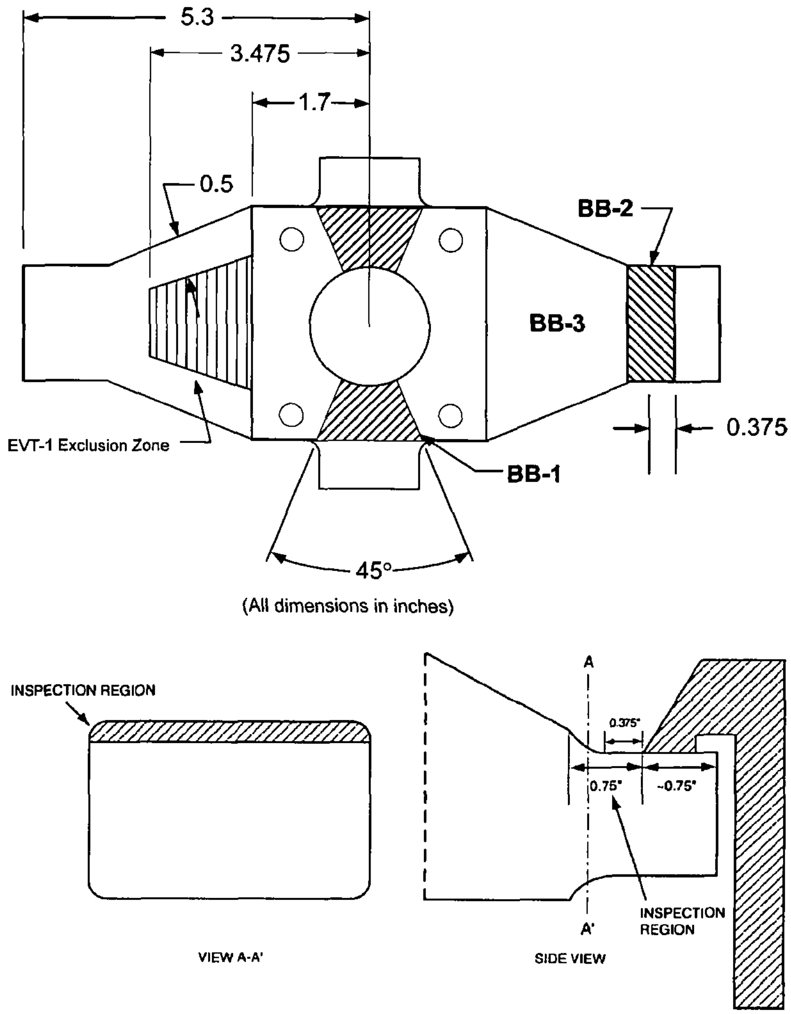

Figure 2-7
Schematic Diagram of the Inspection Regions for the Jet Pump Beam

Note 1: BB-1 and BB-2: hatched regions as shown.

Note 2: BB-3: all other areas from the top surface down to the BB-2.

Note 3: Exclusion zone: region where indications are acceptable for one cycle of operation. The 0.5 inch dimension is from the edge of the beam and from the end of the tapered region and extends 3.475 inches from the bolt-hole centerline.

2.3.2.4 Loading

The majority of the load on the jet pump beams is the applied preload. The applied stress developed by this preload on the beam is a major contributor to determining the time to IGSCC failure. The various beam designs have different applied stresses, as shown in Table 2-2; all are shown for a 25 kip (111 kN) preload.

Table 2-2
Comparison of Maximum Principal Stress without Thermal Relaxation

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2.3.2.5 Susceptibility

2.3.2.5.1 Beam Susceptibility

The only significant failure mechanism associated with the jet pump beam is intergranular stress corrosion cracking (IGSCC) which is aggravated by high stress, poor material properties (including heat treatment) and an aggressive environment.

Under normal water chemistry (NWC) conditions, the environment in the annulus region is highly oxidizing in all BWRs. Radiolysis model calculations predict that the environment has a significant concentration of H_2O_2. Both the initiation and growth of cracks will be promoted by the high electro-chemical potential (ECP) that exists in the annulus region under NWC conditions.

Effective hydrogen water chemistry reduces the amount of oxidizing species in the water, and hence, the ECP. This lowering of ECP is expected to result in an increase in time to initiation of cracking, as well as a reduction in crack growth rate.

All beams are fabricated from Alloy X-750. However, differences in heat treatment and applied stress result in different probabilities of crack initiation. Beams in the EQA condition are expected to fail much earlier than HTA beams. For beams in the HTA condition and under NWC conditions, a statistical evaluation of the Group 2 and Group 3 beams (based on applied stress) has been used to quantify the significant differences in the predicted beam life (i.e., the mean time to beam failure due to IGSCC initiation) in the jet pump beams [17]. The beam life for a Group 2 beam is 40 years. Due to the lower applied stress found in the Group 3 beams, the Group 3 life is significantly longer (240 years). Hydrogen water chemistry conditions would significantly increase both of these values. Table 2-3 shows the predicted life of the Group 2 and Group 3 beams in NWC. (Note that EQA beams are not shown; the U.S. BWR fleet has replaced all EQA beams with HTA.)

Table 2-3
Predicted Beam Life (NWC Conditions)

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Based on this discussion, it can be seen that the various beam designs are predicted to have significantly different lifetimes. Therefore, different inspection intervals are warranted based on design and water chemistry considerations.

2.3.2.5.2 Beam Bolt

Replacement beam-bolt assemblies (beam, bolt, keeper, plate, two screws, two pins as supplied as a unit) were provided with a Type 316L stainless steel rather than a Type 304 stainless steel bolt. Although no IGSCC has been identified on the Type 304 stainless steel bolt, nor would it be expected on this low stress component, the Type 316L stainless steel bolt was used to provide additional IGSCC margin even though the design stress allowable for Type 316L stainless steel is slightly less than that for Type 304 stainless steel.

2.3.2.6 Failure Consequences

Failure of the jet pump holddown beam during operation results in the ejection of the inlet-mixer assembly and loss of jet pump operability. In the absence of the jet pump beam, the only mechanisms tending to resist inlet-mixer ejection are gravity and frictional forces at the interface with the transition piece, at the slip joint with the top of the diffuser, and at the restrainer bracket. The upward loads due to pressure differences and fluid momentum transfer are sufficient to overcome the frictional forces and dead weight, and separate the inlet-mixer from the riser transition piece.

Ejection of an inlet-mixer assembly creates a large leak path between the lower plenum and the annulus region. During a recirculation line LOCA this leak path will affect the ability to maintain 2/3 core coverage as well as LPCI injection. The subsequent safety implications are dependent on the performance of plant ECCS systems.

Inlet-mixer ejection is immediately detectable by numerous jet pump flow, core flow, and power indicators.

2.3.2.7 Inspection Recommendations

A comprehensive fracture mechanics evaluation of the Group 2 and Group 3 jet pump beam designs was performed to establish the flaw tolerance of the designs currently installed in the BWR fleet [8]. The flaw tolerances were used to determine the jet pump beam inspection intervals. The inspection intervals are based on both initiation and crack growth analyses. The initiation data [17] was used to define the time of the initial inspection. The re-inspection intervals are based on the time for an assumed flaw (smaller than the detection limit) to reach a critical size. The time for an assumed flaw to reach the critical size is dependent on the initial flaw depth, the location, and the operating environment.

All holddown beam locations described above (BB-1, BB-2, and BB-3) require inspection as shown in Table 3-1. Inspection requirements depend on beam design, the location inspected, and plant water chemistry. Longer inspection intervals are dependent on credit for mitigation based on requirements given in BWRVIP-62-A [12] as accepted by the NRC. Mitigation credit for jet pump beams is applicable for plants operating on NMCA or OLNC™, but not applicable for plants operating on NWC or HWC. Technical bases for the inspection recommendations in Table 3-1 can be found in BWRVIP- 138, Revision 1 [8] and in the current edition of BWRVIP-03 [18].

No inspection is recommended for the stainless steel beam bolt.

2.3.3 Nozzle Thermal Sleeve

2.3.3.1 Function

The recirculation nozzle inlet thermal sleeve attaches the N2 nozzle safe end to the jet pump riser elbow. The thermal sleeve is designed to provide a pressure retaining flow path for drive flow to the jet pumps. Secondarily, the thermal sleeve reduces temperature variations, and thus thermal loading, on the pressure vessel nozzle.

2.3.3.2 Configurations – Locations TS-1 to TS-4

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**Figure 2-8
Three Configurations for the Thermal Sleeve**

Table 2-4
Thermal Sleeve Configurations

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2.3.3.4 Susceptibility

The relative IGSCC susceptibility of the thermal sleeve welds is primarily dictated by the thermal sleeve configuration and material.

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2.3.3.5 Failure Consequences

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2.3.3.6 Inspection Recommendations

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2.3.4 Riser Pipe

2.3.4.1 Function

The riser pipe connects the inlet nozzle thermal sleeve to the transition piece. The riser directs recirculation flow from the recirculation inlet nozzles to the jet pump inlet-mixers.

2.3.4.2 Configurations – Locations RS-1 to RS-11

Table 2-5 details the different materials and configurations used in the construction of the riser pipe for BWR/3 through BWR/6.

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Figure 2-9
Typical BWR/3 Riser Assembly

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Figure 2-10
Typical BWR/4-6 Riser Assembly

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Figure 2-11
Riser Elbow and Thermal Sleeve

Table 2-5
Riser Materials and Configurations

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2.3.4.4 Susceptibility

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2.3.4.5 Failure Consequences

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2.3.4.6 Inspection Recommendations

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2.3.5 Transition Piece

2.3.5.1 Function

The transition piece is welded to the top of the riser pipe and provides the seating surface for the two inlet-mixer assemblies. The transition piece also provides the load transfer path for the jet pump beams.

2.3.5.2 Configurations – Locations TR-1 to TR-5

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Figure 2-12
Typical Transition Piece

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Figure 2-13
Welded Transition Piece Detail

Table 2-6
Transition Piece Configurations

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2.3.5.4 Susceptibility

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2.3.5.5 Failure Consequences

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2.3.5.6 Inspection Recommendations

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2.3.6 Inlet (Elbow and Nozzle)

2.3.6.1 Function

The inlet is part of the inlet-mixer assembly and consists of a 180 degree elbow and a nozzle. The beam-bolt assembly contacts the top of the elbow and holds the inlet-mixer in place on the transition piece seating surface. The nozzle accelerates the drive flow from the recirculation system and directs the fluid into the mixer section of the inlet-mixer. The nozzle is open to the annulus region so that the low static pressure created by the accelerated nozzle flow will entrain fluid from the annulus into the mixer. The ratio of the drive flow to the entrained flow (or suction flow) is referred to as the M ratio.

2.3.6.2 Configurations – Locations IN-1 to IN-5

Table 2-7 details the materials of construction of the inlet subcomponent for the different plant designs.

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Figure 2-14
Inlet with Single-Hole Nozzle

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Figure 2-15
Inlet with Five-Hole Nozzle

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Figure 2-16
Inlet-Mixer with Clamp Connection

Table 2-7
Inlet Configurations

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2.3.6.4 Susceptibility

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2.3.6.5 Failure Consequences

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2.3.6.6 Inspection Recommendation Technical Basis

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2.3.7 Mixer (Throat)

2.3.7.1 Function

The function of the mixer, or throat, is to mix the drive flow and the suction flow in the jet pump. The bottom of the mixer section forms a slip joint with the top of the diffuser collar. The purpose of the slip joint is to allow for differential thermal expansion between the jet pump assembly and the reactor vessel.

2.3.7.2 Configurations – Locations MX-1 to MX-7

The configurations for the mixer subcomponents are given in Table 2-8.

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Figure 2-17
Typical BWR/3 Mixer without an Adapter

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**Figure 2-18
Typical BWR/3 Mixer with an Adapter**

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**Figure 2-19
Typical BWR/4 Mixers**

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Figure 2-20
Typical BWR/5-6 Mixer Section

Table 2-8
Mixer Configurations

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2.3.7.4 Susceptibility

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2.3.7.5 Failure Consequences

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2.3.7.6 Inspection Recommendations

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2.3.8 Restrainer Bracket Assembly

2.3.8.1 Function

The restrainer bracket assembly is composed of the restrainer bracket, the wedge assembly, and the restrainer bracket adjusting screws.

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2.3.8.2 Configurations – Locations RK-1 to RK-5, WD-1 to WD-2, AS-1 to AS-2

The restrainer bracket configurations are given in Table 2-9. The conditions under which it is joined to the riser pipe are given in Section 2.3.4.

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Figure 2-21
BWR/3 Swing Gate Restrainer Bracket Design

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**Figure 2-22
BWR/3,4 Solid Ring Restrainer Bracket Design**

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Figure 2-23
Solid Ring Restrainer Bracket Design Typical of Most BWR 4-6s

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Table 2-9
Restrainer Bracket Configurations

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Figure 2-24
BWR/3 Wedge Assembly—Welded to Restrainer Bracket (Swing Gate Design)

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Figure 2-25
BWR/3 Wedge Assembly—Welded to Mixer

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Figure 2-26
Typical BWR/4-6 Wedge Assembly

Table 2-10
Wedge Assembly Configurations

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Table 2-11 lists the configuration for the set screws or bolts used in the different plants. Figures 2-22 to 2-23 show the restrainer bracket and adjusting screw configurations.

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Table 2-11
Adjusting Screw Configurations

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2.3.8.4 Susceptibility

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2.3.8.5 Failure Consequences

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2.3.8.6 Inspection Recommendations

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2.3.9 Diffuser Collar

2.3.9.1 Function

The diffuser collar is attached to the top of the diffuser and forms the slip joint with the bottom of the inlet-mixer. The slip joint allows vertical displacement to occur between the diffuser and inlet-mixer, but restricts horizontal displacement. Vertical displacement occurs as a result of differential thermal expansion between the jet pump assembly and the reactor vessel.

2.3.9.2 Configurations – Locations DC-1 to DC-4

Table 2-12 lists the materials for the weld locations in the diffuser collar.

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Table 2-12
Diffuser Collar Configurations

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Figure 2-27
Diffuser Assembly Typical of BWR/3 Plants with External Sensing Line Manifolds

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Figure 2-28
Diffuser Assembly Typical of BWR/3 Plants with Partially Internal Sensing Line Manifolds

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Figure 2-29
Typical BWR/4 Diffuser Assembly

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Figure 2-30
Typical BWR/5 Diffuser Assembly

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Figure 2-31
Typical BWR/6 Diffuser Assembly

2.3.9.4 Susceptibility

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2.3.9.5 Failure Consequences

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2.3.9.6 Inspection Recommendations

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2.3.10 Diffuser and Tailpipe

2.3.10.1 Function

The diffuser and tailpipe provide the flow path for the recirculation flow through the shroud support plate and into the lower plenum. The diffuser shell connects the diffuser collar to the tailpipe, and the tailpipe connects the diffuser shell to the adapter. In plants without adapters, the tailpipe welds to the lower ring.

2.3.10.2 Configuration – Locations DF-1 to DF-4

Table 2-13 lists the different configurations for the diffuser and tailpipe components. Figure 2-27 shows the typical configuration for BWR/3s with entirely external sensing line manifolds. Figure 2-28 shows the typical configuration for BWR/3s with partially internal manifolds. The typical configuration for BWR/4s is shown in Figure 2-29.

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**Table 2-13
Diffuser and Tailpipe Configurations**

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2.3.10.4 Susceptibility

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2.3.10.5 Failure Consequences

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Figure 2-32
Straight Adapter Assembly

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Figure 2-33
Curved Adapter Assembly

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Figure 2-34
Straight Adapter Assembly with Overlap

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2.3.10.6 Inspection Recommendations

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2.3.11 Adapter/Lower Ring

2.3.11.1 Function

The adapter connects the diffuser tailpipe to the shroud support plate. In plants without adapters, the bottom of the tailpipe or lower ring welds directly to the shroud support plate.

2.3.11.2 Configurations – Locations AD-1 to AD-4

Table 2-14 lists the configurations for the adapter/lower ring which is attached to the shroud support ledge at typically the elevation of the H8 and H9 shroud welds.

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Figure 2-35
Lower Ring Connection to Shroud Support Plate Typical of Most BWR/5s and 6s

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2.3.11.3 Loading

The loading of the adapter is similar to that for the tailpipe discussed in Section 2.3.10.

Table 2-14
Jet Pump Adapter Configurations

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2.3.11.4 Susceptibility

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Discussion regarding IGSCC susceptibility and fleet operating experience is provided in Section 2.2.1 above. Detailed review and evaluation of field inspection data and flaw tolerance assessments are documented in Reference 29.

2.3.11.5 Failure Consequences

The consequences of failure of the adapter circumferential welds AD-1 and AD-2 are similar to those of the diffuser shell-to-tailpipe weld (DF-2) discussed in Section 2.3.10, except for plants with a curved adapter design.

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2.3.11.6 Inspection Recommendations

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2.3.12 Jet Pump Sensing Lines

2.3.12.1 Function

The jet pump sensing lines are used to measure the differential pressure inside the diffuser. These measurements are used to determine the flow rate in the pump.

2.3.12.2 Configurations

Table 2-15 lists the configurations for the jet pump sensing lines.

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Figure 2-36
Sensing Line Configuration for BWR/3s With Entirely External Manifold

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Figure 2-37
Sensing Line Configuration for BWR/3-4s With Partially Internal Manifold

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Figure 2-38
Typical BWR/5-6s Sensing Line Configuration

Table 2-15
Sensing Line Configurations

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2.3.12.4 Susceptibility

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2.3.12.5 Failure Consequences

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2.3.12.6 Inspection Recommendations

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2.4 Overview of Changes to Inspection Recommendations in Revision 4

The susceptibility evaluation documented in Section 2.2 and the jet pump component evaluations documented in Section 2.3 identify IGSCC and fatigue as the degradation mechanisms for which inspection is warranted. The inspection program described in Section 3 provides inspection requirements for jet pump components determined to have generic susceptibility to IGSCC or fatigue and whose failure would have an adverse impact on plant safety. No inspections are considered for component locations determined not to be generically susceptible to either IGSCC or fatigue or whose failure would not have an adverse impact on plant safety.

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3 INSPECTION STRATEGY

3.1 Inspection Methods

The following discussions refer to several inspection methods under the general categories of ultrasonic (UT) and visual (VT).

The specific methods are briefly described below. Implementation requirements and definitions are as described in the current edition of BWRVIP-03 [18].

UT: UT is an ultrasonic method of volumetric inspection.

VT-1: VT-1 is defined using the ASME Section XI criteria from the Edition and Addenda applicable to the Owner's in-service inspection program.

Enhanced VT-1: Enhanced VT-1 (EVT-1) is defined in latest revision of BWRVIP-03.

VT-3: VT-3 is defined using the ASME Section XI criteria from the Edition and Addenda applicable to the Owner's inservice inspection program.

3.2 BWRVIP Inspection Guidelines

These inspection guidelines are intended to provide flexible options for inspection while ensuring that structural integrity and/or function of the jet pump are adequately maintained. The guidelines also are generic in nature, based on the overall understanding of the various designs of the jet pump. There may be plant-specific situations where more rigorous inspections are chosen or where less rigorous inspections are justified. For example, if a location for which inspection is required were shown for a specific plant to be solution annealed, a plant-specific evaluation could specify that no inspection is required.

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A detailed description of the technical basis for the inspection program presented in this section can be found in BWRVIP-266 [9].

SILS: The recommendations in this Jet Pump Inspection and Flaw Evaluation Guideline document provide inspections necessary to ensure jet pump integrity for continued safety and replace the inspection recommendations of GE SILS. For assurance of safety, the Jet Pump Inspection and Flaw Evaluation Guideline document replaces the inspection recommendations of:

SIL 330 (Jet Pump Beam Cracks)
SIL 420 (Sensing Line Failures)
SIL 551 (Jet Pump Riser Brace Cracking)

SIL 574 (Jet Pump Adjusting Screw Tack Weld Failures)
RICSIL 086 (Jet Pump Beam Cracks)

However, these SILS do contain other information relative to operational performance and field experience that may assist licensees with investment protection, cost management and optimization of operational performance. Each Licensee should review the current SILS, and stay cognizant of any future changes, for information that may affect reactor operation or performance.

3.2.1 Periodic Inspection

The previous revision of this report specified inspection intervals based on operating cycles. The new criteria use a time-based specification of inspection intervals. This approach simplifies the determination of inspection frequencies. Table 3-1 provides periodic inspection requirements for each inspection location. With the exception of jet pump beams, baseline inspection requirements have been removed from the Table.

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3.2.2 Inspection Technique

In all cases where a VT-1 or EVT-1 inspection is recommended, either a higher resolution visual technique or a suitable NDE examination technique meeting the requirements of the current edition of BWRVIP-03 [18] may be substituted.

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3.2.3 Plant Specific Analyses to Modify/Eliminate Inspection Requirements

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3.2.4 Consideration of Un-inspectable Areas in Partially Accessible Welds

Periodic inspection recommendations are intended to apply to all areas accessible for inspection. Some welds may have segments that are accessible for inspection and portions that are not.

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3.2.5 Inaccessible Welds

Some welds in the jet pump assembly may be completely inaccessible for inspection.

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3.2.6 Inspection Strategy for Accessible and Inaccessible Weld Programs

An overview of the inspection, re-inspection and scope expansion process for the accessible and inaccessible weld inspection programs is shown in Figure 3-1. Note that Section 3.2.7 is invoked when flaws are detected in accessible welds that are similar to inaccessible welds. Scope expansion criteria for accessible and inaccessible welds are contained in Section 3.2.8.

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Figure 3-1
Overview of Accessible and Inaccessible Weld Inspection Programs

Table 3-1
Matrix of Inspection Options

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Table 3-1
Matrix of Inspection Options (Continued)

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Table 3-1
Matrix of Inspection Options (Continued)

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Table 3-1
Matrix of Inspection Options (Continued)

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Table 3-1
Matrix of Inspection Options (Continued)

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Table 3-1
Matrix of Inspection Options (Continued)

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Table 3-1
Matrix of Inspection Options (Continued)

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Table 3-1
Matrix of Inspection Options (Continued)

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Table 3-1
Matrix of Inspection Options (Continued)

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3.2.7 Inspection Program for Inaccessible Welds

As shown in Table 3-1, there are inaccessible welds in the jet pump thermal sleeves (TS-1, TS-2, TS-3, TS-4), in the diffuser (DF-3) and in the lower adapter (AD-1, AD-2). The thermal sleeve welds are inaccessible in most plants; the adapter and diffuser welds are inaccessible only in a few plants.

Two strategies are used to ensure the integrity of inaccessible welds.

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3.2.7.1 Basis for the Allowable Inspection Interval for Inaccessible Welds

Several principles are used to define the inspection strategy for inaccessible welds in the jet pump assembly.

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Section 3.2.7.2 provides the guidelines for identifying similar accessible welds, and Section 3.2.7.3 describes the detailed information and guidelines used to determine the beginning and length of the inspection interval for the inaccessible welds.

3.2.7.2 Similar Accessible Welds

3.2.7.2.1 Susceptibility Categories

Plant-specific accessible welds similar to the inaccessible welds must be identified to use the inspection or leakage evaluation strategy. Section 2.2.1.2 and Section 2.3 identify a number of factors that affect the susceptibility of the various alloys and weld configurations to degradation in the jet pump assembly. For the purpose of evaluating inaccessible welds, the following susceptibility categories are defined:

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3.2.7.2.2 Similar Accessible Welds for Nozzle Thermal Sleeve Welds TS-1, TS-2, TS-3 and TS-4

As indicated in Table 2-4 there are three nozzle thermal sleeve weld configurations.

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3.2.7.2.3 Similar Accessible Welds for Diffuser and Tailpipe Welds DF-3

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3.2.7.2.4 Similar Accessible Welds for Adaptor/Lower Ring Welds AD-1 and AD-2

The adapter connects the diffuser tailpipe to the shroud support plate. Most adapters are fabricated from two pieces.

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3.2.7.3 Guidelines for Determining the Inspection Interval for Inaccessible Welds

The following procedure can be used to determine the plant-specific inspection interval for Priority H/M/L inaccessible welds. The required leakage evaluation is described in Section 5.1.4.

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3.2.7.4 Example Inspection Interval Determination for Inaccessible Welds

The following is an example of the application of this procedure.

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3.2.8 Scope Expansion for Accessible and Inaccessible Weld Inspection Programs

3.2.8.1 Accessible Welds Inspection Program

3.2.8.1.1 General Requirements

The following procedure should be used to expand the inspection scope for accessible welds that are not included in an inaccessible weld program. Also refer to Figure 3-1 for an illustration of the process.

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3.2.8.1.2 Exemptions

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3.2.8.2 Inaccessible Weld Inspection Program

The following procedure should be used to expand the inspection scope for similar accessible welds that are included in an inaccessible weld program. Also refer to Figure 3-1 for an illustration of the process.

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3.2.9 Scope Expansion for Components Other Than Piping Welds

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4 LOADING

In the event that plant-specific flaw evaluations are required, loads and load combinations must be defined. This section describes the details of the various loading and the load combinations that need to be considered to determine the primary and secondary stress levels appropriate for various operating conditions. The flaw evaluation methodology is described in Section 5.

4.1 Applied Loads

The applied loads on the jet pump assembly consist of the following: deadweight, hydraulic loads, seismic inertia, seismic anchor displacements, safety relief valve opening, annulus pressurization, condensation oscillation, chugging, fluid drag, loads due to flow induced vibration, and thermal anchor displacements. Each of these loads are briefly discussed in the following sections.

4.1.1 Deadweight (DW)

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4.1.2 Hydraulic Loads (F1, F2)

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4.1.3 Seismic Inertia

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4.1.4 Seismic Anchor Displacements

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4.1.5 Safety Relief Valve Opening (SRV)

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4.1.6 Annulus Pressurization (AP)

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4.1.7 Condensation Oscillation and Chugging (CO, CHG)

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4.1.8 Fluid Drag and Acoustic Loads

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4.1.9 Flow Induced Vibration (FIV)

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4.1.10 Thermal Anchor Displacements

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4.1.11 Applicability of Hydrodynamic Loads

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4.2 Load Combinations

The load combinations used in the evaluation shall be consistent with the requirements of the plant FSAR, UFSAR or related licensing basis documentation. Typically, Section 3.9 of the FSAR or UFSAR contains the information on this subject, including for some plants, hydrodynamic loads (i.e., "new loads") and/or annulus pressurization loads. The following represents a suggested set of load combinations that may be used for the normal/upset condition if not specified in the plant licensing basis documentation. The (P) suffix indicates a primary load and the (S) suffix indicates a secondary load.

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4.3 Loading for Degraded Jet Pump Assemblies

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4.3.1 Recirculation Pump Vane Passing Frequency

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4.3.2 Turbulent Fluid Flow within the Jet Pump

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4.3.3 Cross flow over the Jet Pumps in the Annulus

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4.3.4 Leakage Flow Mechanism at the Mixer to Diffuser Slip Joint

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5 STRUCTURAL AND LEAKAGE EVALUATION METHODOLOGIES

Structural and leak rate evaluations must be performed to ensure that adequate structural and leakage margins are maintained for cracked jet pump assembly components during operation. This section describes the structural and leak rate evaluation methodologies and computational procedures needed to evaluate cracks in both accessible and inaccessible welds. Crack growth considerations also are provided.

The structural and leakage evaluation approaches for flaws in welds in the riser pipe, inlet mixer and diffuser are presented in Section 5.1. Different evaluation approaches are used for the jet pump beams, riser brace and set screw gaps and are described separately in Sections 5.2, 5.3 and 5.4, respectively.

5.1 Riser Pipe, Inlet-Mixer and Diffuser Locations

This section provides methods for evaluating the acceptability of flaws in the jet pump assembly riser pipe, inlet-mixer and diffuser. Based on observed flaw lengths and assumed crack growth rates, a point in time can be calculated at which the flaws will have grown to such a size that jet pump assembly function may be impaired. Reinspection of the flaws must be scheduled prior to the time at which the flaws have grown to unacceptable sizes. However, in no cases can the results of a flaw evaluation be used to extend the reinspection interval beyond that described in Section 3.

5.1.1 Flaw Characterization

5.1.1.1 NDE Uncertainty

In performing some flaw evaluations, the measured length and depth of observed flaws may need to be adjusted to account for NDE uncertainty. These adjustments shall be made in accordance with current BWRVIP recommendations.

5.1.1.2 Consideration of Welds with Partial Inspection Access

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5.1.1.3 Crack Growth

In evaluating whether an observed crack is acceptable with respect to continued plant operation, assumptions must be made regarding crack growth rates.

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5.1.2 Structural Evaluation

5.1.2.1 Limit Load Evaluation Methodology

The limit load methodology described in Appendix C of ASME Section XI [24] and in [25] is presented in this section as one of the approaches that may be used to determine the critical and allowable flaw lengths for a pipe. Alternative methods may also be used if justified.

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Figure 5-1
Stress Distribution in a Cracked Pipe at Limit Load

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5.1.2.1.1 Z Factor

Some alloys and welds used in jet pump assembly may have lower toughness than is necessary to achieve limit load. These materials include austenitic stainless steel submerged arc welds (SAW) and shielded metal arc welds (SMAW), and alloy 600 and associated weld materials alloy 82/182. When flaws are detected in these materials, a factor, Z, is used to account for the reduced load carrying capacity relative to limit load for the cracked section, and the expression for the failure bending stress is:

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5.1.2.1.2 Flaw Proximity Considerations

If multiple indications are detected during the inspection at a location, then the interactions, if any, between these indications must be accounted for in the structural margin evaluation. Flaw proximity assessment rules provided in BWRVIP-158-A [29] may be applied to address combination of indications.

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5.1.2.1.3 Limit Load Methodology for Multiple Circumferential Indications

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5.1.2.1.4 Allowable Flaw Size Determination

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5.1.2.1.5 Time to Reach the Minimum Acceptable Structural Margin

The time to reach the minimum acceptable structural margin, SF, is the time it takes for a crack to grow from the size at which it is first detected to the allowable flaw size determined from the previous paragraph using the NDE uncertainty, where applicable, and the crack growth rate defined in Section 5.1.1. The time to reach the minimum acceptable structural margin can be obtained from the general expression:

Allowable flaw size = Detected flaw size + Additional allowance due to NDE uncertainty (if appropriate) + Crack growth (crack growth rate * time) at both tips.

5.1.3 Leakage Considerations

Leakage from known flaws as well as from assumed cracks in partially accessible and inaccessible welds must be evaluated as described in Section 5.1.4 to ensure that the leakage is bounded by plant-specific leakage margins.

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5.1.4 Leak Rate Calculation Methods

5.1.4.1 Leak Rate from Cracks Detected in Accessible and Partially Accessible Welds

Leakage from the jet pump assembly into the RPV annulus could come from a number of sources such as through the gap at the slip joint between the diffuser and the mixer, or through the presence of any through-wall cracks in the piping. The leakage rate through a crack, can be estimated assuming incompressible Bernoulli flow through an opening:

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5.1.4.2 Leak Rate from Cracks in Inaccessible Welds

The leakage discussed in Section 5.1.3 includes leakage from cracks in accessible and inaccessible welds. The previous paragraph provides a methodology for determining the leakage from through-wall cracks where the flaw size is known from the inspection results, as defined in Section 5.1.1. This section presents an approach to compute the leak rate from inaccessible welds where the flaw size is unknown.

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5.1.4.2.1 Example Applications

As an example, consider the following conditions.

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Table 5-1
Calculated Leak Rate Distribution for Eight Similar Accessible Welds with Through-wall Flaws

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Figure 5-2
Plot of the Leak Rate Distribution for Similar Accessible Welds and the Estimated Leak Rates for Inaccessible Welds

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Table 5-2
Calculated Leak Rate Distribution for Three Similar Accessible Welds with Through-wall Flaws

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5.2 Jet Pump Beam

Cracking of jet pump hold-down beams has occurred at several operating BWRs. Several beam failures due to these cracks have occurred during plant operation, causing jet pump mixer displacement. For more information regarding the jet pump beam failure incidences, refer to References [1], [33] and [8].

Failed beams and several beams with small cracks have been examined to determine the failure mechanism of the beam.

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5.3 Riser Brace

Riser brace cracking has been observed in a BWR/3 and in a BWR/4. For the GE BWR/3 where cracking was found in the riser brace leaf, a detailed analysis and vibration test program was completed.

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5.4 Set Screw Gap Evaluation

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5.5 Ability of Riser Brace to Prevent Jet Pump Disassembly

In some cases, an intact riser brace may be shown by analysis to be able to prevent jet pump disassembly in the presence of a cracked riser pipe.

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A

LICENSE RENEWAL

The demonstration of compliance with the technical information requirements of the License Renewal Rule (10 CFR 54.21) contained in this appendix was developed based on BWRVIP-41: BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines. Electric Power Research Institute, Palo Alto, CA: 1997. TR-108728. This content is retained for historical context regarding the acceptability of BWRVIP-41 to address the technical information requirements of the license renewal rule. ***As such, content provided on page A-2 and following has not been updated to address revisions to BWRVIP-41 occurring since publication of TR-1011469 and should be considered historical.***

Subsequent revisions to BWRVIP-41 (through this Revision 4) have been reviewed with regard to the intent of this demonstration. Based on this review, the BWRVIP concludes that although changes to the aging management approach and to the structure of the document have occurred, none of these revisions (documented in Appendices D through G) affect the conclusions reached previously in this appendix. The guideline remains adequate to meet the technical information requirements of the License Renewal Rule and ensure that the effects of aging are managed in the period of extended operation. Additionally, there are no new generic TLAAs, exemptions, or Technical Specification resulting from document revisions through Revision 4 of BWRVIP-41.

BWR Jet Pump Assembly Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)

The purpose of Appendix A is to demonstrate that this report provides the necessary information to comply with the technical information requirements pursuant to paragraphs 54.21[a] and [c], and 54.22, and the NRC's findings under 54.29[a] of the license renewal rule (Reference A.[1]). It is intended that the NRC's review and approval of Appendix A will allow utilities the option to incorporate the report and Appendix by reference in a plant-specific integrated plant assessment (IPA) and time-limited aging analysis (TLAA) evaluation. If a license renewal applicant confirms that this report applies to their plant's current licensing basis (CLB) and that the results of the Appendix A IPA and TLAA evaluation are in effect at their plant, then no further review by the NRC of the matters described herein is needed.

A.1 Description of the BWR Jet Pump Assembly and Intended Functions

The jet pumps are located in the annulus region between the core shroud and the vessel wall and provide core flow to control reactor power. Between 6 and 12 pairs of jet pumps are found in BWR/3 through BWR/6 plants, depending on plant rating. BWR/2 plants do not contain jet pumps. During normal operation, each pair of jet pumps is driven by flow from a common riser pipe. The jet pump drive flow is pumped though the recirculation system through the riser and into each jet pump. Additional fluid from the annulus region is entrained into the jet pump flow which is then directed to the lower plenum region.

Figure 1-1 shows result in potential offsite exposure comparable to 10 CFR 100 guidelines (54.4(a)(1)(iii)). Therefore, the intended functions for the jet pump assembly are to:

1. Ensures two-thirds core height re-flooding capability; and
2. Maintains Low Pressure Coolant Injection (LPCI) operability for those plants that use the recirculation system to inject LPCI.

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A.2 Jet Pump Assembly Components Subject to Aging Management Review

Paragraph 54.21(a)(1) of the rule provides the requirements for identifying the jet pump assembly components that are subject to aging management review. To satisfy the requirements of 54.21(a)(1), the guidance provided in the NEI industry guideline (Reference A.[2]) was used to identify the components within the evaluation boundary and then those components are passive and long-lived. The evaluation boundary is that portion of the jet pump assembly that is required to accomplish the intended functions listed in Section A.1 above. The failure consequence assessments in Sections 2.3.1 through 2.3.12 identify the jet pump components that are needed for one or both of the functional requirements.

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A.3 Management of Aging Effects (54.21[a][3])

(a) Description of Aging Effects

For the purpose of this Appendix, the BWR Reactor Pressure Vessel Internals Industry Report (Reference A.[3]) and the resolution to the NRC's questions on the Industry Report are used to identify the aging mechanisms for the jet pump assembly. Aging mechanisms are the causes of the aging effects. The NUREG 1557 (Reference A.[4]) is used to establish the correlation between the aging effects and their associated aging mechanisms. If the industry report concludes that the aging mechanism is significant, then the associated aging effect is included in this aging management review.

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(b) Assessment of Aging Effects and Programs

The jet pump assembly inspection history is described by location in Section 2.3. The generic vendor communications that apply to the jet pump assembly and address the crack initiation and growth and fatigue aging effects are also identified. Significant inspection data is available for some of the jet pump components, e.g., jet pump beams. For other components such as the nozzle thermal sleeve, there is very limited information available due to accessibility limitations

The inspection strategy for jet pump assembly involves baseline inspection and reinspection of the recommended locations using Enhanced visual (VT) or other volumetric methods. The Enhanced visual (VT) examination methods are briefly discussed in Section 3.1. A reference to the implementation requirements and definitions for these methods is also provided. Sections 3.2.1 and 3.2.2 describe the inspection approaches and provide implementation guidance. Should degradation be detected in a jet pump assembly component, Section 3.2.3 presents the scope expansion methodology. Qualitative and quantitative approaches for considering in-accessible areas are described in Section 3.2.5.

Table 3-1 summarizes the inspection recommendations for each jet pump assembly location. These recommendations are based on the results of a conservative safety assessment of each location. The details of the safety assessment are described in Section 2.3. Implementing the inspection strategy requires that it be demonstrated that: 1) the safety assessment for each jet pump component, and 2) the associated evaluation of the safety consequences of component failure, applies to the plant's CLB. Some of the Section 2.3 assessment identified, the need to incorporate plant specific considerations and/or determinations when implementing the inspection strategy. The affected jet pump components are listed below:

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(c) Demonstration that the Effects of Aging are Adequately Managed

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A.4 Time Limited Aging Analyses (54.21[c][1])

The six criteria contained in the NEI industry guideline (Reference A.[3]) were applied to identify the time limited aging analysis (TLAA) issues. That is, those calculations and analyses that:

1. Involve the jet pump assembly,
2. Consider the effects of aging,
3. Involve time-limited assumptions defined by the current operating term,
4. Were determined to be relevant in making a safety determination,
5. Involved conclusions or provide the basis for conclusions related to the capability of the jet pump assembly to perform its intended function, and
6. Are incorporated or contained by reference in the CLB.

should be evaluated to determine TLAA issues. If a plant-specific analysis identified by an application meets all six criteria above, then this analysis will be considered a TLAA for license renewal and evaluated by the applicant.

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EPRI Proprietary Information

A.5 Exemptions (54.21[c][2])

Exemptions associated with the jet pump assembly that contain TLAA analysis issues will be identified and evaluated for license renewal by individual applicants.

A.6 Technical Specification Changes or Additions (54.22)

There are no generic changes or additions to the technical specifications associated with the jet pump assembly as a result of this aging management review to ensure that the effects of aging are adequately managed. The justification for plant-specific changes or additions will be provided by the applicant.

A.7 Demonstration that Activities will Continue to be Conducted in Accordance with the CLB (54.29[a])

Sections A.l, A.2, and A.3 address the requirements 54.21(a) of the rule. The jet pump assembly components that are subject to aging management review are identified, and it is demonstrated that the effects of aging are adequately managed.

Sections A.4 and A.5 address the requirements of 54.21(c) of the rule. Plant-specific time limited aging analyses (TLAAs) and exemptions that require evaluation will be evaluated by the applicant.

Section A.6 addresses the requirements of 54.22 of the rule. There are no generic technical specification changes or additions necessary to manage the effects of aging for the jet pump assembly during the period of extended operation. Plant-specific changes or additions will be justified by the applicant.

Therefore, actions have been identified and have been or will be taken by utilities with BWR plants, such that there is reasonable assurance that the activities authorized by license renewal for the jet pump assembly will be conducted in accordance with the CLB

A.8 References

(1) Title 10 of the Code of Federal Regulations, Part 54, "Requirements for License Renewal of Operating Licenses for Nuclear Power Plants," (60 Federal Register 22461), May 8, 1995.

(2) Nuclear Energy Institute Report NEI 95-10 (Rev. 0), Industry Guideline for Implementing the Requirements of 10 CFR Part 54 the License Renewal Rule.

(3) NUMARC 90-03, BWR Reactor Pressure Vessel Internals License Renewal Industry Report, Revision 1, June 1992.

(4) NUREG-1557, Summary of Technical Information and Agreements from Nuclear Management and Resources Council Industry Reports Addressing License Renewal, October 1996.

B
NRC FINAL SAFETY EVALUATION

Note:

The following Safety Evaluation refers to the original version of BWRVIP-41 (EPRI Report TR-108728).

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

February 4, 2001

Carl Terry, BWRVIP Chairman
Niagara Mohawk Power Company
Post Office Box 63
Lycoming, NY 13093

SUBJECT: FINAL SAFETY EVALUATION OF THE "BWR VESSEL AND INTERNALS PROJECT, BWR JET PUMP ASSEMBLY INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-41)," (TAC NO. M99870)

Dear Mr. Terry:

The NRC staff has completed its review of the Electric Power Research Institute (EPRI) proprietary report TR-108728, "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)". This report was submitted by letter dated October 15, 1997, and was supplemented by letter dated August 4, 1999, in response to a staff's request for information dated February 12, 1999, and by letter dated November 17, 2000, which was in response to the open items in the staff's initial safety evaluation (SE), dated June 20, 2000.

The BWRVIP-41 report, as supplemented, provides generic guidelines intended to present the appropriate inspection and flaw evaluation recommendations to assure safety function integrity of the subject safety-related reactor pressure vessel (RPV) internal components. These guidelines considered degradation susceptibility, degradation mechanisms, loads, and inspection strategies for jet pump assemblies.

The NRC staff has reviewed the proposed revisions to the BWRVIP-41 report and finds, in the enclosed SE, that the revised guidance of the BWRVIP-41 report, with the modifications as described in the enclosed SE, is acceptable for inspection of the subject safety-related RPV internal components. This finding is based on information submitted by the above cited letters. The staff has concluded that licensee implementation of the guidelines in the BWRVIP-41 report, as modified, will provide an acceptable level of quality for inspection and flaw evaluation of the safety-related components addressed.

Carl Terry -2-

The staff requests that you incorporate the staff's recommendations, as well as your responses to other issues raised in the staff's initial SE, into a revised, final BWRVIP-41 report. Please inform the staff within 90 days of the date of this letter as to your proposed actions and schedule for such a revision.

Please contact C. E. (Gene) Carpenter, Jr., of my staff at (301) 415-2169, if you have any further questions regarding this subject.

Sincerely,

Jack Strosnider

Jack R. Strosnider, Director
Division of Engineering
Office of Nuclear Reactor Regulation

Enclosure: As stated

cc: See next page

U.S. NUCLEAR REGULATORY COMMISSION

OFFICE OF NUCLEAR REACTOR REGULATION

SAFETY EVALUATION OF EPRI PROPRIETARY TOPICAL REPORT TR-108728

BWR VESSEL AND INTERNALS PROJECT, BWR JET PUMP ASSEMBLY

INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-41)

1.0 INTRODUCTION

1.1 Background

By letter dated October 15, 1997, as supplemented by letters dated August 4, 1999, and November 17, 2000, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted both proprietary and non-proprietary versions of the Electric Power Research Institute (EPRI) proprietary report TR-108728, "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)".

The staff requested additional information (RAI) in a letter dated February 15, 1999, and the BWRVIP responded to the RAI in a submittal dated August 4, 1999. By letter dated June 20, 2000, the staff provided an initial safety evaluation (SE) with several open items to the BWRVIP. By letter dated November 17, 2000, the BWRVIP provided its response to the open items in the staff's initial SE.

1.2 Purpose

The staff reviewed the BWRVIP-41 report, as supplemented, to determine whether its revised guidance addressed the open items in the staff's initial SE, and if it would provide acceptable levels of quality for inspection and flaw evaluation (I&E) of the subject safety-related RPV internal components. The review considered the consequences of component failures, potential degradation mechanisms and past service experience, and the ability of the proposed inspections to detect degradation in a timely manner.

1.3 Organization of the Report

Because the BWRVIP-41 report is proprietary, this safety evaluation (SE) was written so as not to repeat information contained in the report. This SE gives a brief summary of the general contents of the report in Section 2.0 and the detailed evaluation in Section 3.0 below. The SE does not discuss in any detail the provisions of the guidelines nor the parts of the guidelines that the staff finds acceptable.

ENCLOSURE

2.0 SUMMARY OF BWRVIP-41 REPORT

The BWRVIP-41 report addresses the following topics in the following order:

- Jet Pump Assembly Analysis - The jet pump assemblies are described in detail by a series of illustrations and differences among the various models of BWRs (BWR/3 through BWR/6). The various types of jet pump susceptibility factors and material degradation mechanisms, e.g., intergranular stress corrosion cracking (IGSCC), which has factors that include environment, materials and stress state; fatigue by flow induced vibration and/or thermal cycling; and, thermal embrittlement (aging), that could impact the jet pump assemblies are described in general terms. Potential failure locations are addressed from the standpoint of inspection priority, susceptibility to degradation, and consequences of failures in terms of component functions and plant safety.

- Inspection Strategy - The BWRVIP-41 report recommends the specific locations, NDE methods, and inspection frequencies for examinations of the jet pump assemblies. The report also describes the inspection basis and methods, the recommended baseline inspection scope, the reinspection frequency, scope expansion, and reporting of inspection results.

- Loads and Load Combinations - The various types of loads (e.g., pressure, seismic, etc.) of concern and the load combinations are listed and load combinations are described. Consideration for degraded assemblies are also detailed.

- Structural Evaluation Methodologies - This section presents methods which can be used to determine allowable flaw size determinations for different parts of the assemblies, set screw gap evaluation, and the ability of the riser brace to prevent jet pump disassembly.

The BWRVIP-41 report also contains an Appendix A on Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule, (10 CFR 54.21). Appendix A to the BWRVIP-41 report is not evaluated in this SE report, but will be evaluated under a separate license renewal review.

3.0 STAFF EVALUATION

The staff's June 20, 2000, initial SE provided three open items. The BWRVIP, in its letter of November 17, 2000, addressed these items, which are discussed below.

Issue 1: Un-inspectable Thermal Sleeve Welds

The staff's June 20, 2000, initial SE stated:

> With the exception of the issue described below, as requested in Question 6 of the staff's February 12, 1999, RAI, and stated in BWRVIP's August 4, 1999, response, this review finds that the inspection guidance provided in the subject report to be acceptable:
>
> 1. If analysis cannot be provided to alleviate the weld inspections, what type of recommended inspections are being considered for the thermal sleeve welds? Will the

3

inspections be performed over two inspection cycles with at least 50% of the inspections being performed in the first cycle?

BWRVIP Response:

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This issue is unresolved pending BWRVIP's submittal of the above inspection methodology for the thermal sleeve welds.

BWRVIP's November 17, 2000, response stated:

The BWRVIP will be re-evaluating the need to inspect the hidden welds in the jet pump, core spray and LPCI systems in 2001. This re-evaluation will review the bases for requiring the welds to be examined and determine if a technical basis exists to exclude them from the scope of inspections. However, the issue of hidden welds in the jet pump thermal sleeve is identical to the issue of LPCI hidden welds which was previously resolved between the NRC and BWRVIP. In response to the NRC question on hidden LPCI welds, the BWRVIP responded:

The I&E guidelines contain numerous recommendations that require extensive technological development for their implementation such as inspection of the subject LPCI locations. It is possible that, after adequate attempts, the industry may determine that a recommendation (such as the inspection of the hidden LPCI welds), as written, cannot be implemented as set forth in the I&E guideline. Rather than track this inaccessible location issue separately through the Staff's SE, we propose that the BWRVIP provide a report to the NRC which describes our progress on the development of inspection tooling for inaccessible locations. In addition, to address future situations where a BWRVIP recommendation cannot be implemented, the BWRVIP proposes a programmatic control that includes NRC notification. BWRVIP-42 will be revised to include the below paragraph.

"If, during the course of implementing these recommendations, it is determined that implementation cannot be achieved as described in the I&E guideline, or that meaningful results are not obtained, the user shall notify the BWRVIP with sufficient details to support development of alternative actions. These notifications, as well as planned actions by the BWRVIP, will be summarized and reported to the NRC ."

It is also proposed that, when the other I&E guidelines are revised for final issuance, the paragraph above be included. These actions allow BWRVIP members to identify recommendations that cannot be implemented and provides for appropriate notification and coordination with the NRC.

The BWRVIP intends to revise the Jet Pump I&E Guideline (BWRVIP-41) to contain this same language as discussed in the BWRVIP-42 SE response. Consequently, the issue of hidden thermal sleeve welds should not be considered an open issue. Rather, it should be considered closed by the additional commitment of the BWRVIP to report to the NRC any instances where inspections, as written, cannot be performed.

Staff's Evaluation:

The staff finds that these actions adequately addresses this open item.

Issue 2: Thermal Sleeve Inspection Requirements

The staff's June 20, 2000, initial SE stated:

The staff requested a description of the plant-specific analysis that could be done to alleviate or reduce the inspection requirements of the thermal sleeve welds, TS-1 through TS-4, the riser pipe welds, RS-1, RS-2, and RS-4 through RS-7, the diffuser and tailpipe welds, DF-1 through DF-3, and the adaptor/lower ring welds, AD-1 through AD-3a,b. With respect to the safety consequences, BWRVIP stated that a plant-specific analysis could be done to show that the failure location would not compromise the jet pump's ability to maintain the water level at 2/3 core height. A plant-specific analysis could also show that the failure does not allow the jet pump to disassemble. For other locations, the plant-specific analysis could focus on the redundancies of the core cooling system. Since some of these welds are classified as high priority inspection welds, the staff believes that the description of the plant-specific analyses of the safety consequences should be included in the appropriate sections of the BWRVIP-41 report.

BWRVIP's November 17, 2000, response stated:

The BWRVIP agrees that a description of the plant-specific analyses should be included in the Guideline. The BWRVIP proposes to add the following paragraph to Section 3:

3.2.x Plant-specific Analyses to Modify/Eliminate Inspection Requirements

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EPRI Proprietary Information

Staff's Evaluation:

> The staff finds that this proposed addition to the BWRVIP-41 report adequately addresses this open item.

Issue 3: Structural Evaluation Methodologies

The staff's June 20, 2000, initial SE stated:

> The staff finds the methodology provided for determination of allowable flaw size for the riser, inlet-mixer and diffuser and the set screw evaluation method to be acceptable. Methodology is not provided for the jet pump beam, the riser brace or for an evaluation of the ability of the riser brace to prevent jet pump disassembly. Plant-specific analyses will be needed for evaluation of degradation that is identified for all of the jet pump components.

BWRVIP's November 17, 2000, response stated:

> As noted by the staff, the Guideline does not include flaw evaluation methods for all jet pump components. BWRVIP members would expect to submit to the NRC any flaw evaluations which are not in accordance with methods presented in the Guideline. The BWRVIP proposes to clarify this by revising Section 5 of the guideline to include the following paragraph that comes from Section 4.3 of BWRVIP-76 and provides additional clarification. Furthermore, all future revisions to BWRVIP reports will contain these generic reporting requirements.
>
> > Analytical Evaluations of Inspection Results
> >
> > Analytical evaluations performed to the guidance of this report for the acceptance of inspection results do not require a specific NRC review prior to restart of the plant following a refueling outage. However, results of such analyses shall be provided by the licensee to the NRC. Analytical evaluations that deviate from the guidance of this report (e. g., assumptions, methods, acceptance criteria, etc.), or evaluations of components not described in this report, shall be communicated to the NRC prior to plant restart.

Staff's Evaluation:

> The staff finds that this response adequately addresses this open item.

It should be noted that, with regards to the potential degradation mechanism of thermal embrittlement caused by high fluence levels, the BWRVIP-41 report does not recommend specific inspections of CASS jet pump assembly components to inspect for embrittlement-related degradation beyond that recommended for IGSCC concerns. The staff notes that irradiation embrittlement of CASS components becomes a concern only if cracks are present in the components, and that significant cracking has not been observed in CASS jet pump assembly components. To verify this, the BWRVIP and the NRC's Office of Nuclear Regulatory Research (RES) is engaged in a joint confirmatory research program to determine the effects of high levels of neutron fluence on BWR internals. The results of this program should be used by the BWRVIP to evaluate the need for additional inspections of the CASS jet pump assemblies in the renewal period, and to modify the inspection scope and/or frequency, as needed.

4.0 CONCLUSION

The staff has reviewed the BWRVIP-41 report, as revised, and finds that the guidance of the BWRVIP-41 report is acceptable for inspection of the subject safety-related internal components. The staff has concluded that licensee implementation of the guidelines in the BWRVIP-41 report will provide an acceptable level of quality for examination of the safety-related components addressed in the BWRVIP-41 report.

5.0 REFERENCES

1. Terry, C., BWRVIP, to USNRC, "BWR Vessel and Internals Project: BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)," EPRI TR-108728, October 15, 1997.

2. Carpenter, C.E., USNRC, to C. Terry, BWRVIP, "Proprietary Request for Additional Information - Review of "BWR Vessel and Internals Project, Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)" (TAC No. M99870)," February 12, 1999.

3. Wagoner, V., BWRVIP, to USNRC, "BWRVIP Response to NRC Request for Additional Information on BWRVIP-41 (Reference Project 704)," August 4, 1999.

C

NRC ACCEPTANCE FOR REFERENCING REPORT FOR DEMONSTRATION OF COMPLIANCE WITH LICENSE RENEWAL RULE

Note

Note that the following Acceptance Letter refers to the original version of BWRVIP-41 (EPRI Report TR-108728).

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

2002-283A

October 9, 2002

Carl Terry, BWRVIP Chairman
Constellation Nuclear, Nine Mile Point LLC
Post Office Box 63
Lycoming, NY 13093

SUBJECT: OFFICIAL COPY OF BWRVIP-41 SAFETY EVALUATION DATED JUNE 5, 2001

Dear Mr. Terry:

This letter is being sent to you to confirm that the ADAMS version of the BWRVIP-41 safety evaluation dated June 5, 2001, is an official copy. The statement, "original signed by" indicates that the letter was signed and authorized for approval by NRC management. If you have any further questions on this matter, please contact me at (301)415-2150.

Sincerely,

M. Khanna

Meena Khanna, Materials Engineer
Materials and Chemical Engineering Branch
Division of Engineering
Office of Nuclear Reactor Regulation

cc: BWRVIP Service List

2001-194A

June 5, 2001

Mr. Carl Terry, BWRVIP Chairman
Niagara Mohawk Power Company
Post Office Box 63
Lycoming, NY 13093

SUBJECT: ACCEPTANCE FOR REFERENCING OF "BWR VESSEL AND INTERNALS PROJECT, JET PUMP ASSEMBLY INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-41), EPRI TOPICAL REPORT TR-108728," AND APPENDIX A, "DEMONSTRATION OF COMPLIANCE WITH THE TECHNICAL INFORMATION REQUIREMENTS OF THE LICENSE RENEWAL RULE (10 CFR 54.21)"

Dear Mr. Terry:

By letter dated October 15, 1997, as supplemented by letters dated August 4, 1999, and November 17, 2000, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted both proprietary and non-proprietary versions of the report, "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)," EPRI Topical Report TR-108728, for staff review and approval. The staff requested additional information (RAI) in a letter dated February 15, 1999. The BWRVIP responded to the RAI in a submittal dated August 4, 1999. By letter dated June 20, 2000, the staff provided an initial safety evaluation (SE) with several open items to the BWRVIP. By letter dated November 17, 2000, the BWRVIP provided its response to the open items in the staff's initial SE and on February 4, 2001, the staff issued its final safety evaluation report (FSER). Included in the initial submittal was "Appendix A: BWR Jet Pump Assembly Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)," for staff review in accordance with the License Renewal Rule (10 CFR Part 54).

The BWRVIP-41 report, as supplemented, provides generic guidelines intended to present the appropriate inspection and flaw evaluation recommendations to assure safety function integrity of the subject safety-related reactor pressure vessel (RPV) internal components. These guidelines considered degradation susceptibility, degradation mechanisms, loads, and inspection strategies for jet pump assemblies.

As documented in the enclosed license renewal (LR) FSER, the NRC staff has completed its review of the BWRVIP-41, Appendix A report. As indicated in the LR FSER, the staff finds the BWRVIP-41 report acceptable for licensees participating in the BWRVIP to reference in a LR application to the extent specified and under the limitations delineated in the LR FSER. In order for licensees participating in the BWRVIP to rely on the report, they shall commit to the accepted aging management programs (AMPs) defined therein, and complete the action items described in the LR FSER. By referencing the BWRVIP-41 report and the AMPs in it, and completing the action items, an applicant will provide sufficient information for the staff to make a finding that there is reasonable assurance that the applicant will adequately manage the effects of aging so that the intended functions of the reactor vessel internal components

Carl Terry -2-

covered by the scope of the report will be maintained consistent with the current licensing basis during the period of extended operation.

The staff does not intend to repeat its review of the matters described in the report and found acceptable in the FSER when the report appears as a reference in license renewal applications, except to ensure that the material presented applies to the specified plant.

In accordance with the procedures established in NUREG-0390, "Topical Report Review Status," the staff requests that the BWRVIP publish the accepted version of the BWRVIP-41 report within 90 days after receiving this letter. In addition, the published version shall incorporate this letter and the FSER between the title page and the abstract.

To identify the version of the report that was accepted by the staff, the staff requests that the BWRVIP include "A" following the topical report number (e.g., BWRVIP-41-A).

Sincerely,

/RA/

Christopher I. Grimes, Branch Chief
License Renewal and Standardization Branch
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure: Final Safety Evaluation Report

cc w/encl: See next page

Carl Terry -2-

covered by the scope of the report will be maintained consistent with the current licensing basis during the period of extended operation.

The staff does not intend to repeat its review of the matters described in the report and found acceptable in the FSER when the report appears as a reference in license renewal applications, except to ensure that the material presented applies to the specified plant.

In accordance with the procedures established in NUREG-0390, "Topical Report Review Status," the staff requests that the BWRVIP publish the accepted version of the BWRVIP-41 report within 90 days after receiving this letter. In addition, the published version shall incorporate this letter and the FSER between the title page and the abstract.

To identify the version of the report that was accepted by the staff, the staff requests that the BWRVIP include "A" following the topical report number (e.g., BWRVIP-41-A).

Sincerely,

/RA/

Christopher I. Grimes, Branch Chief
License Renewal and Standardization Branch
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Project No. 704

Enclosure: Final Safety Evaluation Report

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Division of Regulatory Improvement Programs
COVER PAGE

DATE: May 15, 2001

SUBJECT: ACCEPTANCE FOR REFERENCING OF "BWR VESSEL AND INTERNALS PROJECT, JET PUMP ASSEMBLY INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-41), EPRI TOPICAL REPORT TR-108728," AND APPENDIX A, "DEMONSTRATION OF COMPLIANCE WITH THE TECHNICAL INFORMATION REQUIREMENTS OF THE LICENSE RENEWAL RULE (10 CFR 54.21)"

ORIGINATOR: R Anand

SECRETARY: S. Chey

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DOCUMENT NAME:A:\bwrvip-41.wpd

ADAMS ACCESSION NUMBER: **ML** DATE ENTERED: / /01

FORM 665 ATTACHED and filled out: **YES NO**

COMMITMENT FORM ATTACHED: **YES NO**

FINAL LICENSE RENEWAL SAFETY EVALUATION REPORT
BY THE OFFICE OF NUCLEAR REACTOR REGULATION
FOR APPENDIX A TO THE EPRI PROPRIETARY REPORT TR-108728
"BWR VESSEL AND INTERNALS PROJECT, BWR JET PUMP ASSEMBLY
INSPECTION AND FLAW EVALUATION GUIDELINES (BWRVIP-41)"
FOR COMPLIANCE WITH THE LICENSE RENEWAL RULE (10 CFR PART 54)

1.0 INTRODUCTION

1.1 Background

By letter dated October 15, 1997, as supplemented by letters dated August 4, 1999, and November 17, 2000, the Boiling Water Reactor Vessel and Internals Project (BWRVIP) submitted both proprietary and non-proprietary versions of the Electric Power Research Institute (EPRI) proprietary report TR-108728, "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)."

The staff requested additional information (RAI) in a letter dated February 15, 1999, and the BWRVIP responded to the RAI in a submittal dated August 4, 1999. By letter dated June 20, 2000, the staff provided an initial safety evaluation (SE) with several open items to the BWRVIP. By letter dated November 17, 2000, the BWRVIP provided its response to the open items in the staff's initial SE and on February 4, 2001, the staff issued its final safety evaluation report (FSER).

The BWRVIP-41 report, as supplemented, provides generic guidelines intended to present the appropriate inspection and flaw evaluation recommendations to assure safety function integrity of the subject safety-related reactor pressure vessel (RPV) internal components. These guidelines address all welded and bolted locations identified from design drawings of the jet pump assemblies. Susceptibility considerations for the jet pump are presented, as well as the consequences due to failure at each location. Susceptibility and consequences are factored into the inspection recommendations. Inspection approaches vary depending on the type of plant and its associated jet pump configuration. Options are also presented for justification for reduced inspections through plant-specific analysis. These plant-specific analyses are not addressed in the scope of the BWRVIP-41 report, and NRC approval must be obtained on a case-by-case basis, as appropriate.

1.2 Purpose

The staff reviewed the BWRVIP-41 report and its Appendix A, "BWR Jet Pump Assembly Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10 CFR 54.21)," to determine whether its guidance will provide acceptable levels of quality for inspection and flaw evaluation of the subject safety-related RPV internal components within the scope of the report during the period of extended operation. The staff

Enclosure

also considered compliance with the License Renewal Rule in order to allow applicants for renewal the option of incorporating the BWRVIP-41 guidelines by reference in a plant-specific integrated plant assessment (IPA) and associated time-limited aging analyses (TLAA).

Section 54.21 of the License Renewal Rule requires, in part, that each application for license renewal contain an integrated plant assessment (IPA) and an evaluation of TLAA. The IPA must identify and list those structures and components subject to an aging management review and demonstrate that the effects of aging will be adequately managed so that their intended functions will be maintained consistent with the current licensing basis (CLB) for the period of extended operation. In addition, 10 CFR 54.22 requires that each application include any technical specification changes or additions necessary to manage the effects of aging during the period of extended operation as part of the renewal application.

If a license renewal applicant participating in the BWRVIP confirms that the BWRVIP-41 report applies to it and that the results of the Appendix A, IPA and TLAA evaluation are in effect at its plant, then no further review by the NRC staff of the issues described in the documents is necessary, except as specifically identified by the staff. With this exception, the applicant may rely on the BWRVIP-41 report for the demonstration required by Section 54.21(a)(3) with respect to the components and structures within the scope of the report. Under these circumstances, the NRC staff intends to rely on the evaluation in this license renewal safety evaluation report to make the findings required by 10 CFR 54.29 with respect to a particular application, except as necessary to ensure that the BWRVIP-41 report's conclusions apply to the specified plant.

1.3 Organization of this Report

Because the BWRVIP-41 report, as supplemented and modified, is proprietary, this license renewal SE was written so as not to repeat information contained in the propriety portions of the report. The staff does not discuss in any detail the proprietary provisions of the guidelines nor the parts of the guidelines it finds acceptable. A brief summary of the contents of the BWRVIP-41 report is given in Section 2.0 of this license renewal SE, with the NRC staff's evaluation presented in Section 3.0. The conclusions are summarized in Section 4.0. The presentation of the evaluation is structured according to the organization of the BWRVIP-41 report.

2.0 SUMMARY OF THE BWRVIP-41 REPORT

The BWRVIP-41 report and its Appendix A contain a generic evaluation of the management of the effects of aging of the subject components so that the intended functions will be maintained consistent with the CLB for the period of extended operation. This evaluation applies to BWR applicants who have committed to implementing the BWRVIP-41 report and want to incorporate the report and Appendix A by reference into a plant-specific IPA and associated TLAA.

2.1 BWRVIP-41 Topics

The BWRVIP-41 report addresses the following topics in the following order:

- Jet Pump Assembly Analysis - The jet pump assemblies are described in detail by a series of illustrations and differences among the various models of BWRs (BWR/3 through BWR/6). The various types of jet pump assembly susceptibility factors and material degradation mechanisms that could impact the jet pump assemblies are described in general terms, e.g., intergranular stress corrosion cracking (IGSCC), which has factors that include environment, materials and stress state; fatigue by flow induced vibration and/or thermal cycling; and, thermal (aging) embrittlement. Potential failure locations are addressed from the standpoint of inspection priority, susceptibility to degradation, and consequences of failures in terms of component functions and plant safety.

- Inspection Strategy - The BWRVIP-41 report recommends the specific locations, NDE methods, and inspection frequencies for examinations of the jet pump assemblies. The report also describes the inspection basis and methods, the recommended baseline inspection scope, the reinspection frequency, scope expansion, and reporting of inspection results.

- Loads and Load Combinations - The various types of loads (e.g., pressure, seismic, etc.) of concern and the load combinations are listed and load combinations are described. Consideration for degraded assemblies are also detailed.

- Structural Evaluation Methodologies - This section presents methods which can be used to determine allowable flaw size determinations for different parts of the assemblies, set screw gap evaluation, and the ability of the riser brace to prevent jet pump disassembly.

The BWRVIP-41 report also contains Appendix A, "Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule, (10 CFR 54.21)." Appendix A to the BWRVIP-41 report is evaluated in this SE report.

2.2 Identification of Structures and Components Subject to an Aging Management Review

10 CFR 54.21(a)(1) requires that an IPA identify and list those structures and components within the scope of license renewal that are subject to an aging management review. Structures and components subject to an aging management review are those structures and components that (1) perform an intended function, as described in 10 CFR 54.4, without moving parts or without a change in configuration or properties and (2) are not subject to replacement based on a qualified life or specified time period. These structures and components are also referred to as "passive" and "long-lived" structures and components, respectively.

Section 2.0 of the BWRVIP-41 report describes the intended function of the jet pump assembly. The jet pump assembly is required to ensure the capability to shut down the reactor and maintain it in a safe-shut down condition and prevent or mitigate the consequences of accidents that could result in potential offsite exposure comparable to 10 CFR Part 100 guidelines. Therefore, the intended safety functions for the jet pump assembly are to:

1. Ensure two-thirds core height reflooding capability; and
2. Maintain Low Pressure Coolant Injection (LPCI) operability for those plants that use the recirculation system to inject LPCI.

The intended functions are preserved under normal, upset, emergency and faulted conditions.

The failure consequence assessments in Sections 2.3.1 through 2.3.12 of the BWRVIP-41 report identify the jet pump components that are needed for one or both of the functional requirements. These assessments demonstrate that the adjusting screws, diffuser collar, and sensing lines are not required to accomplish either function. Therefore, they are not in the evaluation boundary for licence renewal and are not subject to aging management review. The remaining 10 components in the jet pump assembly are within the evaluation boundary and, as described in Appendix A of the BWRVIP-41 report, they are passive and long-lived, as determined by 10 CFR 54.21(a)(1). These components are listed below:

1. Riser brace
2. Beam/bolt assembly
3. Nozzle thermal sleeve
4. Riser Pipe
5. Transition piece
6. Inlet
7. Mixer
8. Restrainer bracket and wedge assembly
9. Diffuser and tailpipe
10. Adapter/lower ring

Components (1) through (10) except (3) are subject to aging management review. The aging management review of the nozzle thermal sleeve will be provided by individual applicants.

2.3 Effects of Aging

The BWRVIP-41 report identified the aging mechanisms and aging effects for the jet pump assembly using the guidance from NUMARC 90-03, "BWR Reactor Pressure Vessel License Renewal Industry Report," Revision 1, dated June 1992, and the resolution to the NRC's questions on the industry report. The BWRVIP-41 report also used NUREG-1557, "Summary of Technical Information and Agreements from Nuclear Management and Resources Council Industry Reports Addressing License Renewal," dated October 1996, to correlate the aging effects and their associated aging mechanisms. Using these reports, the BWRVIP-41 report concluded that crack initiation/growth and fatigue are included in the aging effects that require aging management review for the jet pump assembly. The industry report also concludes that internals components are not susceptible to thermal embrittlement and neutron embrittlement provided that the materials of construction are wrought austenitic stainless or Ni-Cr-Fe alloy. The susceptibility factors of environment, materials and stress state are discussed in Section 2.2 of the BWRVIP-41 report.

In general, except for the transition piece (because the material is not susceptible to stress corrosion cracking), it was determined that:

- Many locations in the jet pump assembly are subject to an aggressive environment and are therefore characterized by a region of high electrochemical potential (ECP).
- Jet pump assembly materials at locations where a heat affected zone or excessive cold work exists may be susceptible to IGSCC.
- The degradation history suggests that most jet pump assembly components regardless of the grade of material are susceptible, and,
- Regions with the highest expected crack susceptibility are the creviced locations, especially those creviced regions subject to high weld residual stresses.

Some of the welds in the jet pump assembly are creviced. Each weld region is included in the applicable BWRVIP-41 Section 2.2 discussion of the potential failure locations.

2.4 Aging Management Program

10 CFR 54.21(a)(3) requires, for each component identified, that the applicant demonstrate that the effects of aging will be adequately managed so that the intended function will be maintained consistent with the CLB for the period of extended operation. The jet pump assemblies receive a visual inspection in accordance with Section XI of the American Society of Mechanical Engineers (ASME) Code. The as-revised BWRVIP-41 report's aging management program (AMP) includes (a) identification of susceptible components determined to be limiting from the standpoint of thermal aging susceptibility (i.e., ferrite and molybdenum contents, casting process, and operating temperature, explained below) and/or neutron irradiation embrittlement (neutron fluence), and (b) for each "potentially susceptible" component, aging management is accomplished through either a supplemental examination of the affected component based on the neutron fluence to which the component has been exposed during the license renewal term, or a component-specific evaluation to determine its susceptibility to loss of fracture toughness.

Aging effects will be managed by an inspection program incorporating the strategy and recommendations described in Section 3.0 of the as-revised BWRVIP-41 report. The inspection methods and implementation guidance address the:

- Jet pump assembly locations that the revised BWRVIP-41 report requires to be inspected,
- Extent of baseline inspection for each location,
- Extent of reinspection for each location,
- Methodology for scope expansion should degradation be detected, and
- Analysis methods determine the need for corrective action if degradation is detected.

Neutron Embrittlement and/or Thermal Embrittlement

The BWRVIP-41 report does not recommend an inspection of cast stainless steel (CASS) jet pump assembly components, stating that CASS components are not susceptible to IGSCC and that the neutron fluence in the annulus region is not large enough to cause neutron embrittlement and/or thermal embrittlement. However, the BWRVIP-41 report does not contain any data to indicate the threshold for neutron embrittlement and/or thermal embrittlement of CASS and does not identify the neutron fluence levels the CASS jet pump assembly components are subjected to. The staff notes that neutron embrittlement and/or thermal embrittlement of CASS components becomes a concern only if cracks are present in the components. Therefore, if the individual applicant can show that cracks have not occurred in the CASS components, then the staff can conclude that loss of fracture toughness resulting from neutron embrittlement and/or thermal embrittlement will not be a significant aging effect.

Further, the BWRVIP and the NRC's Office of Nuclear Regulatory Research (RES) is engaged in a joint confirmatory research program to determine the effects of high levels of neutron fluence on BWR internals. The results of the joint BWRVIP/RES program into the effects of neutron fluence on BWR internals should be considered by the applicant in evaluating the need for additional inspections of CASS jet pump assemblies in the renewal period. This determination by the applicant will allow the staff to conclude that the applicant has an adequate aging management program for the CASS jet pump assemblies.

It should also be noted that the BWRVIP has stated it intends to revise Section 3.0 of the BWRVIP-41 report to state that, if a meaningful inspection of components, such as the hidden thermal sleeve welds, can not be obtained after a feasibility study on the development of inspection tooling, the licensee will notify the BWRVIP with sufficient details to support development of alternative actions, such as a flaw tolerance evaluation, and the BWRVIP will notify the NRC.

2.5 Time-Limited Aging Analyses (TLAA)

10 CFR 54.21(1)(c) requires that each application for license renewal contain an evaluation of TLAA as defined in 10 CFR 54.3, and that the applicant shall demonstrate that :

(1) The analyses remain valid for the period of extended operation:

(2) The analyses have been projected to the end of the period of extended operation; or

(3) The effects of aging on the intended function(s) will be adequately managed for the period of extended operation.

TLAA are those licensee calculations and analyses that:

(1) involve the jet pump assembly within the scope of license renewal,

(2) consider the effects of aging,

(3) involve time-limited assumptions defined by the current operating term,

(4) were determined to be relevant by the licensee in making a safety determination,

(5) involve conclusions or provide the basis for conclusions related to the capability of the jet pump assembly components to perform their intended function, and

(6) are contained or incorporated by reference in the CLB.

If a plant-specific analysis identified by an applicant meets all six criteria above, the analysis will be considered a TLAA for license renewal and evaluated by the applicant.

The susceptibility of the jet pump components to fatigue (Section 2.2.2 of the BWRVIP-41 report) results in a TLAA issue. Two sources of fatigue need to be considered: system cycling fatigue and vibrational fatigue. System cycling fatigue is due to changes in temperature and pressure. For vibrational fatigue, the time spent at the component's resonant frequency determines whether vibrational fatigue will cause failure and when it will occur. The TLAA issue is evaluated using the requirements in 10 CFR 54.21(c)(1)(iii). Implementation of the inspection strategy described in Section 3.0 of BWRVIP-41 demonstrates that the effects of fatigue on the intended functions will be adequately managed for the period of extended operation.

3.0 STAFF EVALUATION

The staff's FSER on the BWRVIP-41 report for the current term was transmitted by letter dated February 4, 2001, to Carl Terry, BWRVIP Chairman. The NRC staff determined that the contents and recommendations in the BWRVIP-41 report, when coupled with the resolution of the open item regarding CASS, provides a sufficient and acceptable basis for performing examinations and evaluating postulated flaw indications for the subject jet pump components.

The staff has further reviewed the BWRVIP-41 report's Appendix A to determine if it demonstrates that the effects of aging on the jet pump assembly components' intended functions will be maintained consistent with the CLB for the period of extended operation in accordance with 10 CFR 54.21(a)(3). This is the last step in the IPA described in 10 CFR 54.21(a).

Besides the IPA, 10 CFR Part 54 requires an evaluation of TLAA in accordance with 10 CFR 54.21(c). The staff reviewed the BWRVIP-41 report to determine if the TLAA covered by the report was evaluated for license renewal in accordance with 10 CFR 54.21(c)(1).

3.1 Structures and Components Subject to Aging Management Review

The staff agrees that the jet pump components are subject to aging management review because they perform their intended functions without moving parts or without a change in configuration or properties. The staff concludes that BWR applicants for license renewal must identify the jet pump components as subject to aging management review to meet the applicable requirements of 10 CFR 54.21(a)(1).

3.2 Intended Functions

The staff agrees that the intended safety functions of the jet pump assembly components are as stated. Their safety function is to ensure a two-thirds core height reflooding capability and to maintain Low Pressure Coolant Injection (LPCI) operability for those plants that use the recirculation system to inject LPCI.

3.3 Effects of Aging

The information necessary to demonstrate compliance with the requirements of the license renewal rule 10 CFR 54.21 is provided in Appendix A of the BWRVIP-41 report. The BWR Reactor Pressure Vessel Industry Report NUMARC 90-03, Revision 1, and the resolution to the NRC's questions on that Industry Report were used to identify the aging mechanisms for the jet pump assembly components. If the industry report concluded that the aging mechanism is significant then the aging mechanism is included in the aging management review. Using this methodology, the BWRVIP determined that crack initiation and growth and fatigue are the only aging effects that required aging management review.

The staff notes that, since the jet pump assembly is constructed using several cast austenitic stainless steel (CASS) components, thermal embrittlement and neutron embrittlement is a potential degradation mechanism. It is important to note that thermal and/or neutron embrittlement of CASS components becomes a concern only if cracks are present in the components, and that cracking has not been observed in CASS jet pump assembly components. Thermal embrittlement and/or neutron embrittlement does not, in and of itself, cause cracking to occur, but it does reduce the structural margin of the material in resisting crack propagation due to other initiators (e.g., IGSCC or fatigue).

The staff finds that thermal embrittlement and/or neutron embrittlement are aging effects that also require aging management review for the jet pump assembly. The applicant shall evaluate all four aging effects (crack initiation/growth, fatique, thermal embrittlement, and neutron embrittlement) for applicability to their facility.

3.4 Aging Management Programs

The staff evaluated the BWRVIP's aging management program to determine if it contains the following 10 elements constituting an adequate aging management program for license renewal:

(1) Scope of Program: The program contains preventative measures to mitigate fatigue and stress corrosion cracking (SCC); inservice inspection (ISI) to monitor the effects of SCC on the intended function of the components, and repair and/or replacement as needed to maintain the ability to perform the intended function. Based on the BWRVIP's determination of the two aging effects that require aging management review for the jet pump assembly (e.g., crack initiation and growth and fatigue), and the staff's concerns regarding thermal and/or neutron embrittlement, the applicant shall evaluate all four aging effects for applicability to their facility.

(2) Preventive Actions: Maintaining high water purity reduces susceptibility to SCC. Hydrogen additions are effective in reducing electrochemical (corrosion) potentials in the recirculation piping system, but are less effective in the core region. Noble metal additions, through a catalytic action, appear to increase the effectiveness of hydrogen additions in the core region. The staff has reviewed and approved the BWRVIP-62 report, which describes these mitigative actions.

(3) Parameters Monitored or Inspected: Inspection and flaw evaluation are performed in accordance with the NRC-approved BWRVIP-41 guidelines.

(4) Detection of Aging Effects: Inspection in accordance with the NRC-approved BWRVIP-41 guidelines, as modified to resolve the item on thermal sleeve weld inspection, will ensure that degradation is detected before any loss of the intended function of the jet pump assembly welds.

(5) Monitoring and Trending: The inspection schedule, in accordance with ASME Section XI, IBW-2400, and reliable examination methods provide timely detection of cracks. Scope of examination expansion and re-inspection beyond the baseline inspection are required if flaws are detected.

(6) Acceptance Criteria: Any degradation is evaluated in accordance with applicable NRC-approved BWRVIP guidelines. Flaws detected in CASS components are evaluated in accordance with the applicable procedures of ASME Section XI, IWB-3500.

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(7) Corrective Actions: Repair is in conformance with the NRC-approved BWRVIP-51 report and/or ASME Section XI, IWA-4000 and IWB-4000. Replacement is in accordance with IWA-7000 and IWB-7000.

(8) & (9) Confirmation Process and Administrative Controls: Site QA procedures, review and approval processes and administrative controls are implemented in accordance with the requirements of Appendix B to 10 CFR Part 50 will continue to be adequate for the license renewal period.

(10) Operating Experience: Instances of SCC have occurred in jet pump assemblies (NRC Bulletin 80-07), hold down beams (NRC Information Notice (IN) 93-101), and jet pump riser pipe elbows (IN 97-02).

The staff's final safety evaluation of the BWRVIP-41 report was transmitted by letter dated February 4, 2001 to Carl Terry, BWRVIP Chairman. For the reasons set forth in that FSER, the staff concluded that the inspection strategy and evaluation methodologies discussed in the BWRVIP-41 report, as revised to include the resolution of the identified issues, is acceptable. Implementation of the above inspection program provides reasonable assurance that the identified aging effects will be adequately managed such that the intended functions of the subject safety-related RPV internal components will be maintained consistent with the CLB in the extended operating period.

3.5 Time Limited Aging Analyses (TLAA)

The susceptibility of the jet pump components to fatigue results in a TLAA issue and requires plant-specific evaluation by the applicant. The TLAA issue is evaluated using the requirements in 10 CFR 54.21(c)(1)(iii). Implementation of the inspection strategy described in Section 3.0 of the BWRVIP-41 report demonstrates that the effects of system cycling and vibration fatigue on the intended functions will be adequately managed for the period of extended operation.

Based on the staff's concerns regarding thermal and/or neutron embrittlement, thermal and/or neutron embrittlement is a TLAA issue. Thermal and/or neutron embrittlement of CASS components becomes a concern only if cracks are present. If the applicant can show that cracks do not occur in the CASS components, then it can be concluded that the loss of fracture toughness resulting from thermal and/or neutron embrittlement will not be a significant aging effect. These conclusions also apply for the period of extended operation.

4.0 CONCLUSIONS

The staff has reviewed the subject BWRVIP-41 report and the associated Appendix A, as submitted by the BWRVIP. On the basis of its review, as set forth above, the staff concludes that the BWRVIP-41 report and the associated Appendix A provides an acceptable demonstration that the BWRVIP member utilities referencing this report will adequately manage the aging effects of reactor vessel components within the scope of the report, with the exception of the noted renewal applicant action items set forth in Section 4.1 below, so that there is reasonable assurance that the jet pump components will perform their intended functions in accordance with the CLB during the period of extended operation. The staff also concludes that, upon completion of the renewal applicant action items, the BWRVIP-41 report and the associated Appendix A provides an acceptable evaluation of time-limited aging analyses for the jet pump assembly components for the BWRVIP member utilities for the period of extended operation.

Any BWRVIP member utility may reference this report in a license renewal application to satisfy the requirements of (1) 10 CFR 54.21(a)(3) for demonstrating that the effects of aging on the reactor vessel internal components within the scope of this topical report will be adequately managed and (2) 10 CFR 54.21(c)(1) for demonstrating the appropriate findings regarding evaluation of TLAA for the jet pump components for the period of extended operation. The staff also concludes that, upon completion of the renewal applicant action items set forth in Section 4.1 below, referencing the BWRVIP-41 report and its Appendix A in a license renewal application and summarizing in an FSAR supplement the aging management programs and the TLAA evaluations contained in this report, will provide the staff with sufficient information to make the necessary findings required by Sections 54.29(a)(1) and (a)(2) for components within the scope of this report.

4.1 <u>Renewal Applicant Action Items</u>

The following are license renewal applicant action items to be addressed in the plant-specific license renewal application when incorporating the BWRVIP-41 report and the associated Appendix A in a renewal application:

(1) The license renewal applicant is to verify that its plant is bounded by the BWRVIP-41 report. Further, the renewal applicant is to commit to programs described as necessary in the BWRVIP-41 report to manage the effects of aging on the functionality of the jet pump components during the period of extended operation, including actions planned to mitigate the issue concerning the inspection of welds that are presently inaccessible, and the thermal and/or neutron embrittlement TLAA. Applicants for license renewal will be responsible for describing any such commitments and identifying how such commitments will be controlled. Any deviations from the aging management programs within the BWRVIP-41 report described as necessary to manage the effects of aging during the period of extended operation and to maintain the functionality of the reactor vessel components or other information presented in the report, such as materials of construction, will have to be identified by the renewal applicant and evaluated on a plant-specific basis in accordance with 10 CFR 54.21(a)(3) and (c)(1).

(2) 10 CFR 54.21(d) requires that an FSAR supplement for the facility contain a summary description of the programs and activities for managing the effects of aging and the evaluation of TLAA for the period of extended operation. Those applicants for license renewal referencing the BWRVIP-41 report for the jet pump components shall ensure that the programs and activities specified as necessary in the BWRVIP-41 report are summarily described in the FSAR supplement.

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(3) 10 CFR 54.22 requires that each application for license renewal include any technical specification changes (and the justification for the changes) or additions necessary to manage the effects of aging during the period of extended operation as part of the renewal application. In its Appendix A to the BWRVIP-41 report, the BWRVIP stated that there are no generic changes or additions to technical specifications associated with the jet pump assembly as a result of its aging management review and that the applicant will provide the justification for plant-specific changes or additions. Those applicants for license renewal referencing the BWRVIP-41 report for the jet pump assembly shall ensure that the inspection strategy described in the BWRVIP-41 report does not conflict or result in any changes to their technical specifications. If technical specification changes do result, then the applicant should ensure that those changes are included in its application for license renewal.

5.0 REFERENCES

1. Letter from Carl Terry, BWRVIP, to USNRC, "BWR Vessel and Internals Project, BWR Jet pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)," EPRI Report TR-108728, dated October 1997.

2. Letter from Jack R. Strosnider, USNRC, to Carl Terry, BWRVIP, "Final Safety Evaluation of the BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41), "EPRI Report TR-108728, dated February 4, 2001.

3. C.E. Carpenter, USNRC, to C. Terry, BWRVIP, "Proprietary Request for Additional Information - Review of "BWR Vessel and Internals Project, Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)" (TAC No.M99870), dated February 12, 1999.

4. NUREG-1557, Summary of Technical Information and Agreements from Nuclear Management and Resources Council Industry Reports Addressing License Renewal, October 1996.

5. V. Wagoner, BWRVIP, to USNRC, "BWRVIP Response to NRC Request for Additional Information on BWRVIP-41 (Reference Project 704)," August 4, 1999.

6. C.I. Grimes, USNRC to D. J. Walters, Licence Renewal Issue No. 9-0030, "Thermal Aging Embrittlement of Cast Austenitic Stainled\ss Steel Components" dated May 19, 2000.

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REVISION 1 RECORD OF REVISIONS

BWRVIP-41-R1	Information from the following documents was used in preparing the changes included in this revision of the report: 1. "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41)," EPRI Report TR-108728, October 1997. 2. Letter from C.E. Carpenter (NRC) to Carl Terry (BWRVIP Chairman), "Proprietary Request for Additional Information - Review of BWR Vessel and Internals Project, Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP -41)," dated 2/12/99 (BWRVIP Correspondence File Number 99-056A). 3. Letter from Carl Terry (BWRVIP Chairman) to C.E. Carpenter (NRC), "BWRVIP Response to NRC Request for Additional Information on BWRVIP-41 (Reference Project 704)," dated 8/4/99 (BWRVIP Correspondence File Number 99-306). 4. Letter from J. R. Strosnider (NRC) to Carl Terry (BWRVIP Chairman), "Initial Safety Evaluation Report, "BWR Vessel and Internals Project, BWR Jet Pump Inspection and Flaw Evaluation Guidelines (BWRVIP-41)," (TAC NO. M99870)," dated 6/20/2000 (BWRVIP Correspondence File Number 2000-184). 5. Letter from Carl Terry (BWRVIP Chairman) to C.E. Carpenter (NRC), "BWRVIP Response to NRC Safety Evaluation of BWRVIP-41" dated 11/17/00 (BWRVIP Correspondence File Number 2000-319). 6. Letter from Jack Strosnider (NRC) to Carl Terry (BWRVIP Chairman), "Final Safety Evaluation of the "BWR Vessel and Internals Project, BWR Jet Pump Inspection and Flaw Evaluation Guidelines (BWRVIP-41)" (TAC NO. M99870)," dated 2/4/01 (BWRVIP Correspondence File Number 2001-062). 7. Letter from Christopher Grimes (NRC) to Carl Terry (BWRVIP Chairman), "Acceptance for Referencing of "BWR Vessel and Internals Project, Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP -41), EPRI Topical Report TR-108728"and Appendix A "Demonstration of Compliance with the Technical Information Requirements of the License Renewal Rule (10CFR54.21)," dated 6/5/2001 (BWRVIP Correspondence File Number 2001-194A). 8. "BWRVIP-94: BWR Vessel and Internals Project, Program Implementation Guide," EPRI Report 1006288, August 2001. 9. "BWRVIP-138: BWR Vessel and Internals Project, Updated Jet Pump Beam Inspection and Evaluation Guidelines," EPRI Technical Report 1008213, December 2004. Details of the revisions can be found in Table D-1.

Table D-1
Revision Details BWRVIP-41 Rev. 1

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
MVT-1 to be changed to EVT-1	Response to RAI (99-307)	MVT-1 changed to EVT-1 throughout.
The following paragraph will be included in all revised I&E Guidelines: *"If, during the course of implementing these recommendations, it is determined that implementation cannot be achieved as described in the I&E guideline, or that meaningful results are not obtained, the user shall notify the BWRVIP with sufficient details to support development of alternative actions. These notifications, as well as planned actions by the BWRVIP, will be summarized and reported to the NRC."*	Response to Initial SE (2000-319)	Discussion included in BWRVIP-94. No change to BWRVIP-41.
Include a description of plant specific analyses that can be used to modify/eliminate inspections.	Response to Initial SE (2000-319)	New Section 3.2.6 added. Section content derived from SE response with minor changes.
Include paragraph from BWRVIP-76 regarding submittal of flaw evaluations to NRC	Response to Initial SE (2000-319)	Discussion included in BWRVIP-94. No change to BWRVIP-41.
	General Comment	Section 5.1.2.2 revised to indicate that crack growth rates used in flaw evaluations shall be in accordance with current BWRVIP guidance.
All I&E Guidelines to be revised to replace CSVT and MVT by EVT-1, VT-1 or VT-3. "EVT-1 will be specified as the primary technique when fine, tight IGSCC is a primary concern. In other locations, VT-1 or VT-3 will be used as appropriate."	Response to SE on BWRVIP-03, Item 3.3-4 (99-115)	MVT-1 changed to EVT-1 throughout.

Table D-1
Revision Details BWRVIP-41 Rev. 1 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
BWRVIP will propose response to “Use of NDE Uncertainty” at a later date.	Response to SE on BWRVIP-63 (2001-189)	New Section 5.1.1 added: Flaw Characterization
	General Comment	Limit load equations in section 5.1 revised for consistency among BWRVIP I&E Guidelines.
	General Comment	Sect 3.1: Note regarding cleaning deleted. Cleaning is addressed in BWRVIP-03. Reference to BWRVIP-03 changes to refer to the “current edition of BWRVIP-03.” (Also in Section 3.2.4.)
	Editorial	Section 3.2.4: Rationale for use of MVT-1 vice EVT-1 deleted.
	Editorial	Table 3.3.1 revised: Inspection requirements for MX-2 for BWR/5 and /6 changed to “None Required” for consistency with Section 2.3.7.7.
	Editorial	“Enhanced VT-1” changes to “EVT-1” throughout.
	Editorial	Section 2.3.3.7 revised.
	Editorial	Section 3.2.7 revised.
	Editorial	Table 3.3.1 revised (“Note” for locations TS-1, TS-2, TS-3, TS-4, DF-3, AD-1 and AD-2 revised).
	Editorial	Section 5.1.2.1 revised for consistency with other I&E Guidelines.
	General Comment	Inspection recommendations for jet pump beams revised in Section 2.3.2, Table 3.3.1 and Section 5.1.3 per BWRVIP-138.
	Editorial	Section 2.3.4.7: “fillet” deleted.

Table D-1
Revision Details BWRVIP-41 Rev. 1 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
	Editorial	Figure 2-31 revised to show welds DF3-a and DF3-b
	Editorial	Section 3.2.3: Note added regarding scope expansion for wedges.
	Editorial	Figures 3.2.1-1 and 3.2.2-1 deleted. References to figures deleted from sections 3.2.1 and 3.2.2.
	Editorial	Reference 15 deleted; references 16-21 renumbered accordingly. New reference 21 added.
	Editorial	Section 5.1.2.4: Use of 2x for uninspected region clarified.
	General Comment	Section 2.3.8.7 and Table 3.3-1: Wedge inspections revised based on recent operating experience.
	Editorial	Section 5.1.2.3: Equation edited.
	General Comment	Sampling approach for selecting inspection locations defined (Sect. 3.2.1, 3.2.2) per BWRVIP Inquiry Resolution 2005-002.
End of Revisions		

E
REVISION 2 RECORD OF REVISIONS

BWRVIP-41-R2	Information from the following documents were used in preparing the changes included in this revision of the report: 1. "BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines (BWRVIP-41, Rev. 1)," EPRI Report 1012137, 2005. 2. "BWRVIP-138, Rev. 1: BWR Vessel and Internals Project, Updated Jet Pump Beam Inspection and Evaluation Guidelines," EPRI Technical Report 1016574, December 2008. Details of the revisions can be found in Table E-1.

Table E-1
Revision Details BWRVIP-41 Rev. 2

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Non-technical format changes and updates to reference documents	EPRI publication guidelines	Format changes and updates to references were made throughout the document. Revision bars are not indicated for the format changes.
	NEI-03-08	Added Section 1.3 Implementation Requirements
	General Comment	Updated figures 2-1, 2-2 & 2-3 for additional clarity on the locations of welds RS-8 through RS-11.
Revise BWRVIP-41 Rev. 1 to include updated information contained in BWRVIP-138 Rev. 1	BWRVIP-138, Rev. 1	Section 2.3.2.3 and Figure 2-7 revised to add clarity to beam inspection regions.
	General Comment	Updated Section 2.3.2.4 and Table 2-2 on beam design loading description.
Revise BWRVIP-41 Rev. 1 to include updated information contained in BWRVIP-138 Rev. 1	BWRVIP-138, Rev. 1	Revised content in 2.3.2.5.1 Beam Susceptibility.
	General Comment	Revised 2.3.2.7 Inspection History to clarify beam operating experience by beam region.
Revise BWRVIP-41 Rev. 1 to include updated information contained in BWRVIP-138 Rev. 1	BWRVIP-138, Rev. 1	Revised 2.3.2.8 Jet Pump Beam Bolt Inspection Recommendation Technical Basis and Tables 2-4 and 2-5 to reflect the revised inspection frequencies for Group 2 and Group 3 beams.
	General Comment	Revised 2.3.4.7 Riser Brace Inspection Recommendation Technical Basis. In light of recent industry OE the BWRVIP is currently not pursuing analyses to reduce or alleviate inspection of the Riser Brace welds. Deleted "In addition, the BWRVIP is pursuing analyses which may reduce or alleviate inspection of the RS-1, RS-2, and RS-4 through RS-7 welds."
	General Comment	Deleted BWRVIP-41 Rev. 1 Table 2-4 Probability of Failure

Table E-1
Revision Details BWRVIP-41 Rev. 2 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
	BWRVIP-219	Updated Tables 2-5 & 3.3-1 (BB-1, BB-2 & BB-3) to clarify applicability of HWC inspection frequencies for jet pump beams
	General Comment	Updated 2.3.10.7 to add clarity for inspection of AD-3a and AD-3b welds
Update Inspection Definitions	BWRVIP-03 Rev. 11	Section 3.1 updated definition of Enhanced VT-1 to require need to resolve the ASME Code Section XI VT-1 0.044 inch characters and updated VT-3 for clarity.
	BWRVIP Interpretation 2005-001	Section 3.2.1 page 3-2, added clarification of the start of the first Inspection Cycle.
	BWRVIP Interpretation 2008-004	Section 3.2.2 added clarification of Re-inspection Cycles
	General Comment	Table 3.3-1, Section 4, Updated Figure Number references for RS-8, RS-9, RS-10 and RS-11
Revise BWRVIP-41 Rev. 1 to include updated information contained in BWRVIP-138 Rev. 1	BWRVIP-138, Rev. 1	Updated Table 3.3-1 to update the inspection options for the B-1, BB-2 and BB-3 regions of the Group 2 and Group 3 beams. Removed inspection strategy for BWR/3 and Group 1 beams as all U.S. BWR's have replaced these designs with Group 2 or Group 3 beam designs.
	General Comment	Updated Table 3.3-1 Section 8, WD-1 Baseline and Re-Inspection text to provide additional clarity to the guidance.
	BWRVIP-03 Rev. 10 & BWRVIP Interpretation 2007-006	Updated Table 3.3-1 notes for DF-3, AD-1, AD-2 and AD-3a,b.
	General Comment	Section 4.2 updated for consistency with Implementation Requirements, the word 'should' changed to 'shall'
	ASME Section XI, Appendix C	Updated the Z-factor information contained in Section 5.1.2.1 "Limit Load Methodology".
	Editorial	Updated Section 6 References

F

REVISION 3 RECORD OF REVISIONS

BWRVIP-41-R3	Information from the following documents were used in preparing the changes included in this revision of the report: 1. *BWRVIP-41, Revision 2: BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines.* EPRI, Palo Alto, CA: 2009. 1019570. Details of the revisions can be found in Table F-1.

Table F-1
Revision Details BWRVIP-41 Rev. 3

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
	General comment	Revised note to Revision 3 to point out that the NRC has not reviewed the content contained in Revisions 1, 2 or 3 of BWRVIP-41. Nevertheless, the technical revisions to this report are more conservative than contained in the original issuance of BWRVIP-41 (EPRI Report TR-108728). It is the BWRVIP's position that implementation should proceed as normal per Section 1.3 and BWRVIP-94, Rev. 1.
Revised Table 2.3.3-1	Utility comment	Table 2.3.3-1 revised to change the material of the thermal sleeve to 316L for the Cooper Nuclear Station
Identify welds that are inaccessible for inspection	General comment	Revised Section 2.3.3.7 to address inspection methodology for TS-1, 2, 3 and 4 welds Revised Section 2.3.10.7 to address inspection methodology for DF-3 weld for LaSalle 1 and Fermi 2 Revised Section 2.3.11.7 to address inspection methodology for AD-1 and AD-2 for LaSalle 1a and Fermi 2 Revised Table 3-1 to include the above statements
	Internal comment	Revised Section 2.3.8.4 to state that tack welds are unlikely to produce IGSCC. Also stated that cracking in the stellite surface of wedges has been observed but no but no adverse effects from this cracking have been reported
Update definitions of inspection methods	Internal comment	Revised Section 3.1 to update definitions

Table F-1
Revision Details BWRVIP-41 Rev. 3 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Incorporate inspection strategy for inaccessible welds	General comment	Revised Section 3.2.5 to address partially inaccessible welds. Revised Table 3.3-1 for TS-1, 2, 3, 4; AD-1, -2; and DF-3 welds to indicate that until an inspection technique becomes available the inaccessible welds shall be evaluated according to the guidelines in Section 3.2.8 Added Section 3.2.8 to incorporate inspection strategy for inaccessible welds
Incorporate leakage evaluation for inaccessible welds	General comment	Revised Section 5 to incorporate methodology for determining leakage from inaccessible welds
Update Section 5 for clarity	Internal comment	Restructured Section 5 to improve clarity
	Editorial	Renumbered References in Section 6
End of Revisions		

G
REVISION 4 RECORD OF REVISIONS

BWRVIP-41-R4	Information from the following documents were used in preparing the changes included in this revision of the report: 1. *BWRVIP-266, BWR Vessel and Internals Project, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.* EPRI, Palo Alto, CA: 2012. 1025140. 2. *BWRVIP-234: BWR Vessel and Internals Project, Thermal Aging and Neutron Embrittlement Evaluation of Cast Austenitic Stainless Steels for BWR Internals.* EPRI, Palo Alto, CA: 2009. 1019060. 3. *BWRVIP-158-A: BWR Vessel and Internals Project, Flaw Proximity Rules for Assessment of BWR Internals.* Electric Power Research Institute, Palo Alto, CA: 2010, 1020998. 4. *BWRVIP-41, Revision 3: BWR Vessel and Internals Project, BWR Jet Pump Assembly Inspection and Flaw Evaluation Guidelines.* EPRI, Palo Alto, CA: 2009. 1021000. 5. Supplemental Jet Pump Wedge Rod Inspection Guidance (BWRVIP Correspondence 2014-019). Revision 4 to BWRVIP-41 incorporates the results of BWRVIP-266 [9]). Details of the revisions can be found in Table G-1.

Table G-1
Revision Details BWRVIP-41 Rev. 4

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
All Sections	Various	Cited references were revised to include the most recent revision, where applicable. Section references were updated as needed as some section reorganization occurred in this Revision.
Various Sections	N/A	Reference to Millstone was removed from Table 1-1, various Section 2 Tables, and Table 3-2. Reference to Millstone was also removed from selected Section 2.3 susceptibility and inspection recommendation subsections. Millstone Unit 1 is now decommissioned.
Section 1		
Revised Section 1.1, Background	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	The background section was expanded to give a more complete history of jet pump inspection guidance; from early inspection guidance documents up through the current BWRVIP-41 revision.
Revised Section 1.2, Objectives and Scope	Editorial	Minor editorial changes.
Revised Section 1.2, Objectives and Scope	Editorial	Text indicating that the report was developed under an Appendix B QA program removed. Revision 4 was not developed under Appendix B QA.
Revised Section 1.3, Implementation Requirements	N/A	This section is revised to note that implementation of new requirements cannot be implemented until approved by the NRC. Additionally, within the list of sections identified as “needed” guidance, “Section 4.2” was revised to “Section 4”.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 2		
Revised Section 2.0, Jet Pump Assembly Analysis	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	General changes to this section include: Removing or revising information about material susceptibility as recent data analyses indicate changes to the earlier conclusions concerning susceptibility. Removal of individual inspection history sections as this revision is based on a significant amount of recent inspection data. Addition of operating experience sections for IGSCC and fatigue to summarize new inspection findings.
Revised Section 2.1, Jet Pump Configuration and Function	Editorial	Removed "rectangle" symbol in second line of third paragraph and inserted "-degree" to preclude future conversion issues.
Revised Section 2.2.1.1, Environment.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Section 2.2.1.1 discusses environment considerations associated with IGSCC. This section was updated to include discussion of hydrogen water chemistry technologies that have been widely adopted by U.S. BWRs (i.e., HWC-M, NMCA, and OLNC™).
Revised Section 2.2.1.2, Materials.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Section 2.2.1.2 discusses IGSCC susceptibility with regard to material. This section was updated to: 1) Address IGSCC resistance of solution annealed components installed without field welding. 2) Update material susceptibility information based on the current state of knowledge.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 2		
Revised Section 2.2.1.3, Tensile Stress.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Section 2.2.1.3 discusses the effect of tensile stress on IGSCC susceptibility. This section was edited to emphasize the increased propensity for IGSCC associated with field welds and in particular final field assembly welds (e.g., RS-1).
Inserted new Section 2.2.1.4, Operating Experience: IGSCC	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Operating experience discussion added to summarize the results contained in BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program. Subsections are provided for stainless steel weld HAZs and Ni-base alloys.
Section 2.2.2, Fatigue Susceptibility	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	General discussion updated to reflect the results contained in BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.
Section 2.2.2.1 heading added, "Fatigue Load Sources" and related discussion revised.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Relocated discussion related to fatigue load sources into a separate subsection. Discussion is updated to reflect the results contained in BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.
Section 2.2.2.2 heading added, "IGSCC Interaction".	Editorial	Relocated discussion related to fatigue interaction with IGSCC into a separate subsection.
Inserted new Section 2.2.2.3, Operating Experience: Fatigue	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Operating experience discussion added to summarize the results contained in BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 2		
Revised Section 2.2.3, Embrittlement	BWRVIP-234, BWR Vessel and Internals Project, Thermal Aging and Neutron Embrittlement Evaluation of Cast Austenitic Stainless Steels for BWR Internals.	Updated the embrittlement susceptibility discussion to include the 60-year neutron fluence evaluation results contained in BWRVIP-234.
Removed Section 2.2.4, Conclusions	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	This section was removed because it was out of date and provided limited value to the report. A new section; Section 2.4, Overview of Changes to Inspection Recommendations in Revision 4" provides an updated set of conclusions based on the results of BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.
Revised Section 2.3, Potential Failure Locations.	N/A	Language regarding timing for performance of baseline inspections was removed since all baseline exams have been completed for some time now. Additional editorial changes were also made.
Revised "Susceptibility" sections 2.3.1.4, 2.3.3.4, 2.3.4.4, 2.3.5.4, 2.3.6.4, 2.3.7.4, 2.3.9.4, 2.3.10.4, and 2.3.11.4.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Susceptibility discussions for the riser brace, thermal sleeve, riser pipe, inlet, mixer, throat, diffuser and tailpipe, and adapter / lower ring welds were updated based on the results of BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program. Additionally, susceptibility discussions were streamlined to refer back to the susceptibility discussion provided in Section 2.2 and to remove extraneous information related to priority and inspection locations.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 2		
Revised "Inspection Recommendation" sections 2.3.1.6, 2.3.3.6, 2.3.4.6, 2.3.5.6, 2.3.6.6, 2.3.7.6, 2.3.9.6, 2.3.10.6, and 2.3.11.6. Note: These were sections 2.3.1.7, 2.3.3.7, 2.3.4.7, 2.3.5.7, 2.3.6.7, 2.3.7.7, 2.3.9.7, 2.3.10.7, and 2.3.11.7 in the previous revision of BWRVIP-41.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Renamed these sections from "Inspection Recommendation Technical Basis" to "Inspection Recommendations". Detailed technical bases for the inspection recommendations made in these sections are provided in BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program. Inspection recommendation discussions for the riser brace, thermal sleeve, riser pipe, inlet, mixer, throat, diffuser and tailpipe, and adapter / lower ring welds were updated based on the results of BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program. Inspection requirements were clarified as needed through the addition of lists of locations where inspection is required and lists of locations where no inspection is required. Discussion in these sections was edited to remove reference to baseline vs. reinspection since baseline inspections are now complete. Discussion in these sections was also edited to remove reference to specific inspection techniques since the revised inspection program now includes UT inspection criteria. This discussion was somewhat redundant since Table 3-2 specifies inspection methods and periodic inspection intervals. Reference to Table 3-2 was added in place of this discussion. For Section 2.3.3.6, Thermal Sleeves, reference to the criteria for inaccessible welds was revised from 3.2.8 to 3.2.7, consistent with changes in Section 3 described below. A statement clarifying the inspection program for inaccessible welds and referencing Table 3-2 was also added.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 2		
Removed "Inspection History" sections 2.3.1.6, 2.3.2.7, 2.3.3.6, 2.3.4.6, 2.3.5.6, 2.3.6.6, 2.3.7.6, 2.3.8.6, 2.3.9.6, 2.3.10.6, 2.3.11.6, and 2.3.12.6.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	The inspection histories in these sections were based on older data. Therefore, these inspection history sections were removed. A summary of operating history based on up to date data is provided in new Sections 2.2.1.4 and 2.2.2.3 for IGSCC and fatigue, respectively.
Revised Table 2-4	Reviewer comment	Revised to show the Browns Ferry Unit 1 thermal sleeve as a Type A configuration that it does not include any creviced locations.
Revised Section 2.3.2.2.2, BWR/4-6 Beam Design – Group 1	Editorial	Replaced "this report" with BWRVIP-41 Revision 3 and made this reference past tense.
Revised Section 2.3.2.3, Inspection Regions	Editorial	The operating experience information referenced is now in Section 2.2.4 instead of Section 3.2.7.
Revised Section 2.3.2.5.1, Beam Susceptibility	Editorial	Minor editorial corrections and clarifications.
Revised Section 2.3.2.7, Inspection Recommendation Technical Basis	N/A, changes made do not affect the technical results. Rather they improve the section organization and clarity.	Consistent with the approach taken for weld locations, this section was renamed from "Inspection Recommendation Technical Basis" to "Inspection Recommendations". Detailed technical bases for the inspection recommendations made in these sections are provided in BWRVIP-138 Revision 1. This section was edited to frame inspection requirements in terms of "NMCA and OLNC" vs. "other chemistries" rather than using "NWC" vs. "HWC" and notation to clarify that only NMCA and OLNC can be credited for HWC inspection intervals. Tables 2-4 and 2-5 were removed. These tables were redundant to Table 3-2. Instead, reference to Table 3-2 is provided. The conclusion that no inspection is required for the stainless steel beam bolt is added to this section for clarity.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Section 2		
Table 2-4 (previously Table 2-6 in Revision 3), Themal Sleeve Configurations	Editorial	A clarifying table note was added to highlight that N2 nozzle replacement activities could have affected the information contained in the Table and plants should verify thermal sleeve material and configuration. This is a clarification only. A similar note already existed in Section 2.3.3.2 above, but was not directly tied to the table.
Revised Section 2.3.4.2, Configuration – Locations RS-1 to RS-11	Editorial	Clarified that welds RS-8 through RS-11 are "groove welds with reinforcing fillets" and not simply "fillet welds".
Revised Section 2.3.4.5, Failure Consequences (Riser Pipe)	Editorial	Reference to Section 5.3 revised to refer to Section 5.5 instead.
Revised Section 2.3.6.1, Inlet (Elbow and Nozzle)	Editorial	Removed "rectangle" symbol in second line of third paragraph and inserted "-degree" to preclude future conversion issues.
2.3.8.4, Susceptibility (Restrainer Bracket Assembly)	Editorial	Minor editorial clarification.
2.3.8.4, Inspection Recommendations (Restrainer Bracket Assembly)	N/A	Consistent with the approach taken for weld locations, this section was renamed from "Inspection Recommendation Technical Basis" to "Inspection Recommendations". Specific reference to VT-1 examination is removed and replaced with "visual examination". Reference to Table 3-1 is added.
Revised Section 2.3.10.2, Configuration – Locations DF-1 to DF-4	Editorial	Added a clarification that BWR/6s have an additional ring weld between the tailpipe and lower ring, resulting in two welds at DF-3 shown as DF-3a and DF-3 in Figure 2-31.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Revised Section 2.3.11.6 to clarify that for plants with curved adapters (Fermi 2 and LaSalle 1), failure of AD-1 or AD-1 results in loss of LPCI function only for Fermi 2.	Reviewer comment	The existing text implied that failure of AD-1 or AD-2 for plants with curved adapters results in both loss of 2/3 core coverage and loss of LPCI function. LaSalle 1 has a LPCI coupling and therefore loss of LPCI function does not occur as a result of an AD-1 or AD-2 failure. This clarification does not change the consequence result for the AD-1 or AD-2 welds at LaSalle 1, nor the inspection requirements contained in Table 3-1.
Added new Section 2.4, Overview of Changes to Inspection Recommendations in Revision 4.	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	This new section summarizes the inspection program revision recommendations provided in BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.
Section 3		
Revised Section 3.1, Inspection Methods	N/A	The definitions of VT-1 and VT-3 are revised to use the ASME Section XI criteria from the Edition and Addenda applicable to the Owner's inservice inspection program.
Revised Section 3.2, BWRVIP Inspection Guidelines	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	This section is revised to specify that the revised inspection guidance provided is dependent on implementation of HWC-M, NMCA, or OLNC consistent with BWRVIP-62 Revision 1, BWRVIP-219, and BWRVIP-245. Prior language addressing BWRVIP efforts to reduce inspection requirements based on HWC was removed.
Removed Section 3.2.1, Baseline Inspection	N/A	Baseline inspections have now been completed, so the requirements for baseline inspections are removed from the report.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Revised Section 3.2.2, Re-Inspection (Section 3.2.1, Periodic Inspection, in Revision 4)	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	This section is now Section 3.2.1, 'Periodic Inspection". As baseline inspections are complete, the term "re-inspection" is changed to "periodic inspection." This section was revised to incorporate new bases for periodic inspection requirements found in BWRVIP-266. Additionally, the section was amended to allow a 6-month extension of the inspection interval to accommodate outage scheduling.
Revised Section 3.2.3, Inspection Technique (Section 3.2.2 in Revision 4)	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	This section was modified to summarize the approach toward introduction of UT-based inspection intervals.
Revised Section 3.2.5, Consideration of Un-inspectable Areas in Partially Accessible Welds (Section 3.2.4 in Revision 4)	Editorial	Minor editorial change to remove the term "baseline" and replace "re-inspection" with "periodic inspection".
Revised Sections 3.2.6 and 3.2.7 (Sections 3.2.5 and 3.2.6 in Revision 4)	Editorial	Section references updated.
Revised Figure 3-1, Overview of Accessible and Inaccessible Weld Inspection Programs	Editorial	The flowchart was revised to clarify the process for determining inspection requirements for both accessible and inaccessible welds. Note the chart is fundamentally the same, but appropriate section changes were made.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Revised Table 3-2, Matrix of Inspection Options (Table 3-1 in Revision 4)	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	Table 3-2 (Now Table 3-1 due to elimination of Table 3-1 in Revision 3) was revised to include new periodic inspection requirements and options in accordance with BWRVIP-266. Additionally, the inspection requirements for jet pump beam locations (BB locations) were reorganized to present period inspection criteria in terms of NMCA & OLNC vs. other chemistry types. This is not a technical change, but rather a clarification of the existing requirements. Throughout the table, minor editing was performed to improve the consistency and clarity of the inspection requirements. In a number of cases, clarifying notes were added.
Revised Section 3.2.8.1 (Section 3.2.7.1 in Revision 4), Accessible Welds Inspection Program (Scope Expansion)	BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.	This section (now 3.2.8.1) was revised to include new exemptions associated with welds having prior UT exams. Exemptions are based on recent inspection data and associated evaluations presented in BWRVIP-266, Technical Bases for Revision of the BWRVIP-41 Jet Pump Inspection Program.
Wedge rod inspections added Section2.3.8.6	BWRVIP supplemental inspection guidance (BWRVIP Correspondence (2014-019)	Section 2.3.8.8 and Table 3-1 revised to include wedge rod inspection guidance.
Section 3.2.10 (Section 3.2.9 in Revision 4), Scope Expansion for Components Other Than Piping Welds	Editorial	Text modified to remove baseline" and "re-inspection" terms. Reference to baseline inspection is no longer meaningful in the context of weld inspection since all baseline exams are now complete.
Section 5		
Section 5.1.4.2	Editorial	Table and Section references updated as needed to reflect changes made in Section 3.

Table G-1
Revision Details BWRVIP-41 Rev. 4 (Continued)

Required Revision	Source of Requirement for Revision	Description of Revision Implementation
Revised Section 5.1.1.2, Consideration of Welds with Partial Inspection Access	Editorial	The section describing inaccessible weld inspection strategy is 3.2.7 in Revision 4. The reference was updated consistent with this change.
Revised Section 5.1.2.1.2, Flaw Proximity Considerations	BWRVIP-158-A: BWR Vessel and Internals Project, Flaw Proximity Rules for Assessment of BWR Internals.	Language describing flaw proximity considerations was updated to include reference to BWRVIP-158-A and to clarify the applicability of the guidance contained in BWRVIP-158-A for jet pump weld evaluations.
Appendices		
Revised Appendix A, License Renewal	N/A	An introduction to Appendix A is added to note the Appendix content as historical and to document the BWRVIP conclusion that although the aging management strategy contained in BWRVIP-41 has been significantly modified from the Version of BWRVIP-41 that the NRC License Renewal SE is based on, none of the program revisions alter the conclusion reached previously; that the guideline is adequate to meet the technical information requirements of the license renewal rule and to ensure the effects of aging are managed in the period of extended operation.
Revised Appendix B, NRC Final Safety Evaluation	N/A	An introductory statement was added to note that the SE contained in this Appendix refers to the original version of this report.
Revised Appendix C, NRC Acceptance for Referencing Report for Demonstration of Compliance with License Renewal Rule	N/A	An introductory statement was added to note that the License Renewal Acceptance Letter refers to the original version of this report.
End of Revisions		

Export Control Restrictions

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